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RUDIMENTS

OF THE

ART OF CONSTRUCTING AND REPAIRING COMMON ROADS.

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TO WHICH IS PREFIXED,

A general Survey of the principal Metropolitan Roads.

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GENERAL SURVEY

OF THE

PRINCIPAL METROPOLITAN ROADS.

WITH the view of arriving at some principles to guide us in the laying out of roads in new districts of country, I am not aware that any more instructive study could be pointed out, than a brief survey of the physical features and geographical conditions which characterise the lines of the present great roads leading from the metropolis to various parts of the kingdom.

It may be objected to this, that there are few districts which present any striking resemblance to the country surrounding the metropolis; and that, consequently, rules laid down as applicable to the construction of roads in this part of England, would fail in their application to other districts, and to distant countries. It may also be objected that, with the exception of those designed by the Romans, the roads of this country were not the work of any set of people possessing superior wisdom and resources to the native inhabitants, but were, in fact, gradually contrived and executed by the natives themselves, during a long course of centuries, whilst they were gradually emerging from barbarism; and were continued and improved, step by step, in proportion to the increase of our towns, the spread of our commerce, and the advancement of our intellectual resources. This latter fact would certainly lead to the conclusion that our roads, instead of being traced with reference to the physical features of the country, would often be made subservient in their direction to other features and conditions; such as the position of towns or hamlets already built, to the location of manufacturing establishments, or the existence here and there of valuable minerals, requiring the aid of superior land carriage in order to render them of practical value.

The first of these objections exists more in appearance than reality; for, although there may be many practical

details peculiar to different districts of country when we come actually to lay out a road in them, there is still much similarity in the broad features which distinguish the surface of the earth; and there is no such great variety in these features as to call for many distinct divisions in attempting a description of them. For instance, a line of road may pass over a perfectly flat country, or it may lie in the direction of a valley, or it may pass obliquely over both valleys and their intervening ridges. Subdivisions of these cases are possible, but still these are the three great conditions under which roads have to be laid out: and some roads have to encounter all three of these cases.

To the second objection it may be answered, that while we observe the faults committed by our ancestors in the designs of their roads, we shall at the same time learn to avoid them in our own colonies, where we profess to bring the experience of civilised life to bear upon the wild desert, the boundless prairie, or the tangled jungle. In applying ourselves to the formation of roads in new countries, we have peculiar mathematical resources to guide us in the selection of those lines which are most direct, at the same time that they are not less judicious than other routes. It is probable that the use of surveying instruments, or, at least, the use of instruments to determine the relative bearings and position of objects, was unknown at the period when most of the roads in this country were first formed; and that not until the construction of maps such as those of the Ordnance Survey, did the extreme and often unnecessary circuitousness of these roads become apparent. Now, although in the colonies we do not yet possess Ordnance maps, and may not possess them for many years, yet we are able, by means of the theodolite, or even the circumferentor, to determine not only the exact position of the terminal points of the road, but to lay down the whole length of it, to show the bearing and direction of every part, and so to bring in the important elements of straightness and direction in finally determining the route, and comparing various proposed lines together. To proceed, then, with our review of the existing roads of this country.

CAMBRIDGE ROAD.

The first in order we shall take, is that which passes out of London in nearly a northerly direction—namely, the

road from London to Cambridge. This road emerges from the east end of London, and, passing through Kingsland, Stamford-hill, Tottenham High-cross, Tottenham, Edmonton, Enfield, Cheshunt, Broxbourne, Hoddesdon, and Ware, proceeds to Cambridge; from which place continuations branch off to Huntingdon and Ely. The first peculiarity in this road is observed at Stamford-hill, where it crosses that remarkable horseshoe ridge of high ground which encircles the metropolis on the west, north, and east sides. This ridge, which is popularly well-known as the Hampstead or Highgate range of hills, does not terminate at either of those places, but is continued round in a circular, or, more properly, a horseshoe form, by the following points, which will usually indicate the highest part of the ridge. Commencing with the highest ground in Hyde-park, the ridge may be traced by Paddington, Barrow-hill, Primrose-hill, Hampstead, Caen-wood, Highgate, Hornsey-lane, and Mount Pleasant—about one mile east of which winds the New River, on its way to London. The ridge here almost dies away, for about a mile and a half, into a depression, through which some ancient river has probably had its course; but it appears again about half a mile west of the Cambridge road, forming the elevated points of Stamford-hill, Upper Clapton, and Homerton, where, after skirting the valley of the Lea for about three miles, it falls off into the extensive flats of Bow, Bromley, and Stratford.

Stamford-hill is a ridge of inconsiderable height, with an approach of about one in twenty on each side. This inclination, although too steep to be sanctioned in the modern system of road-making, which ought to have nothing steeper than one in thirty, is here of less importance, as both the inclinations are short, the steep part not exceeding a quarter of a mile on either side.

Soon after crossing Stamford-hill, the road enters the valley of the River Lea, and keeps parallel to the Lea and Stort navigation, at a distance varying between half a mile and one mile, as far as Bishop's Stortford, where the navigation terminates. The road through Ware branches off at Stortford, and proceeds by Royston to Cambridge.

Immediately beyond Stamford-hill, the Cambridge line of the Eastern Counties railway approximates nearly to the turnpike road, and accompanies it in its course up the valley of the Lea, the railway keeping the central position

between the road and the river. The river Lea, it should be observed, on approaching the foot of Stamford-hill, is turned out of its course by the horseshoe ridge already described; and accordingly flows round it through Hackney-marshes, and, passing by Bow and Bromley, falls into the Thames at Bugsby's-reach, immediately below Blackwall. The railway, also, entirely avoids the high ground between Stamford-hill and its terminus at Shoreditch. Commencing at Stratford, out of the Norfolk line of the Eastern Counties, the Cambridge line winds round on the east side of the Lea, passing through the Hackney and the Leyton-marshes, until it crosses the river a little below Tottenham-mills, and then proceeds, as already described, between the road and the river. The great *detour* made by the railway will be seen from the fact, that from Shoreditch to Tottenham High-cross the distance by railway is eight miles; while, by road, the distance between the same points is only four and a half miles.

A little south of Kingsland, this road crosses the Regent's Canal, which, by its communication with the Grand Junction, and the canals of the Midland counties, affords facilities for the transport of the Mount-sorrel and Nuneaton syenite; and, accordingly, we find that the first tract of this road, namely, for about two miles north of Whitechapel church, is made of this stone. The syenite is also partially used with broken flint gravel for about a mile further. It does not, however, appear to be used for the steep slopes of Stamford-hill, a situation in which it would prove more serviceable than in the flat district of Kingsland and Dalston. Over Stamford-hill, and for several miles beyond, the road metalling consists entirely of broken flints.

THE EPPING ROAD.

The next great road we propose to notice, proceeds out of London through Bow and Stratford, entering Epping-forest at Leytonstone. It continues through the forest about nine miles, passing by Snaresbrook, Woodford, Chigwell-hill, Buckhurst-hill, High-beech, Jack's-hill, and Epping. The road proceeds over Epping-plain and Thornwood-common through Potter-street to Harlow, where it joins the Cambridge road last described, about half way between Hoddesdon and Sawbridgeworth. This road, for about ten miles of its course, namely, between Stratford and Epping,

may be said to occupy nearly the summit or watershed line of the high country between the rivers Lea and Roding. The ascent from Leytonstone to Woodford (two and a half miles) is rapid, and the road then keeps nearly the summit of the country, passing northwards towards High-beech, parallel to the stream of a small feeder of the Lea. Beyond High-beech its direction is parallel to a feeder of the Roding, nearly as far as the Wake Arms on Jack's-hill. Passing over this high summit, the road somewhat descends in approaching Epping. On leaving Epping, the road ascends over Thornwood-common towards the sources of Cripsey-brook, one of the principal feeders of the Roding. Although it is here rather east of the real summit between the Lea and the Roding, the road nearly divides the country between them as far as its termination at Harlow.

An interest of no common kind appears to attach itself to this forest road. It is probable that its track is very ancient, and there is every reason to suppose that the wandering gipsy, the cattle drover from the northern and eastern counties, and the pedlar—in days of yore a much more important character than at present—made use of it long before the valleys of the Lea or the Roding were occupied by roads. For military purposes, it is easy to see why a high district of country, lying between two valleys, should afford the most favourite site for a road, provided its undulations offered no very striking obstacle. We know that in former days this great forest of Epping was a royal hunting-ground; and there are not wanting, in the present day, names to serve as memorials of such a fact. About two miles north-east of Chingford, stands Queen Elizabeth's Lodge; while Fox Inn, Royal Oak Inn, Hunter's Hall, and similar places scattered about the forest, remind us of the sport which was there followed, and of the noble personages who shared in it. There are many indications of wells and springs of medicinal and healing virtues all along the main road through the forest. These were, probably, waters containing certain proportions of alkaline substances, such as those of Epsom, Wandsworth, Bagnigge Wells, Beulah Spa, and numerous other spots in and about London.

The ancient character of this road, and the fact of its having been a favourite highway for the traffic of former times, (marked by a circumstance from which one might also deduce another consequence, pointing to the lawless violence of that period,) is to be found in the name of a

spot—Turpin's Cave—which will be found marked on the Ordnance Map, in a hollow on the right of the road, opposite the twelfth mile from London. The many natural advantages enjoyed by this road, passing through an elevated district, chiefly of gravel, with patches of clay, retaining water where required, and yet abundantly drained by the numerous feeders of the Lea and the Roding, joined to the magnificent prospects which swell before the view on either side, have caused it to become a favoured residence with many of the most respectable and wealthy citizens of London; and, accordingly, the Forest road boasts an unusually large number of houses, villas, and mansions, of superior character.

Although the track of this road is probably very ancient, it has been much improved of late years by cutting down the hills and filling the valleys, so as to reduce the inequalities of the undulating surface of the forest. The improvement thus effected may be judged from the fact that on the Chingford road, a parallel line lying on the west side of the forest, where the irregularities are not so prominent as in this central line, there are inclinations as steep as eight and nine to one; whereas, on the whole of the Epping road, there is no inclination exceeding one in thirty.

Where the road has been lowered, the cuttings are composed of a very gravelly clay, which has uniformly slipped to a great extent, no precautions having been taken to prevent the slipping, by drainage or otherwise. The same remark applies to the embankments, which, besides absorbing the material from the cuttings, have been partially made up from side cuttings, excavated at the base on both sides, where the land is not of much value. The whole metalling of this road consists of the round pebbly flint gravel, which is found so abundantly in most parts of the forest; and in summer, or tolerably dry weather, the surface is commonly in very good order.

This road, as far as Stratford, is principally composed of Mount-sorrel syenite; in addition to which, from Whitechapel church, where the street-paving ends, as far as Bow, a trackway, of eight feet wide on each side, is pitched with regular granite paving stones, similar to the street pitching. This is of great service for slow heavy traffic, by which the trackways are chiefly used. This part of the road is from fifty to sixty feet in width between the footpaths.

CHIPPING ONGAR ROAD.

THE next road in order is that which passes up the valley of the Roding to Chipping Ongar, where it joins a line of road leading out of the Epping road last described, at Epping itself, to Chelmsford. This Chipping Ongar road branches out of the Epping road at Leytonstone, and passing off in a north-easterly direction, falls into the valley of the Roding, nearly opposite Woodford. Keeping close to the river for about a mile, it crosses over at Woodford-bridge, and then proceeds on the east side, by Chigwell and Wolston-lodge, up to Abridge, where it again approaches the river. Beyond Abridge, the course of the river is nearly eastward for about two miles, during which the road closely follows it, crossing at Passingford-bridge, from which point they both pursue a north-easterly course to Chipping Ongar.

There are great defects in this road, and it evidently appears to have been designed to suit a succession of private and inferior interests, instead of the general and public convenience. Between Woodford-bridge and Abridge, a distance of four miles, this is more particularly the case; the road for some distance between these points, as at Chigwell for instance, being fully a mile from the river, without answering any ostensible purpose, except that of encountering very high and undulating ground, instead of a perfect flat. Every engineer knows that, in following the course of a river, either for a railway or a common road, it is advisable to recede from the river, where secondary valleys intervene, so as to cross these high up, where the depth of filling will be small; and, on the other hand, to approach the river where promontories of high land intervene with these secondary valleys, so as to reduce the depth of cutting as much as possible. The very opposite has been done in this case, inasmuch as between Abridge and Woodford-bridge the river is turned from its course, and diverted to the west, by the high projecting land jutting out from Hainault-forest; and the road, instead of following this westward bend of the river, actually projects in a corresponding manner to the eastward, so as to catch a great deal of the high ground of the forest, both north and south of Chigwell. This defect in the construction of the road has probably been occasioned in accommodating an extensive group of villas and superior residences in the neighbour-

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hood of Chigwell, Wilcox-green, the Rolls, Wolston-lodge, &c.; and, although it might be very desirable for the owners of these to seek an elevated situation on the flank of Hainault-forest, commanding views across the low country of the Roding, and bringing into the landscape the many objects of interest which crowd the opposite slopes of Epping-forest, this still appears to be a very imperfect reason for carrying the road over so undulating a country, to the permanent injury and mischief of all who have ever to use the road. The first error is made in carrying the road suddenly down from Snaresbrook-farm to the Roding, where the descent increases from one in thirty-two to one in seventeen, and continues at this latter rate for some distance.

Again, at Woodford-bridge the road rises much too suddenly from the river, and strikes at once into the high ground, which, in all such cases, should be gradually skirted.

A considerable part of the ascent from the river to the turnpike-gate, at Wilcox-green, is at the rate of one in twenty. The road then continues with moderate undulations till about the tenth mile, when it descends to Chigwell-brook, at the rate of one in twenty-five, which increases at one place to one in nineteen. The ascent from the stream up to the vicarage is at the rate of one in twenty. Beyond the vicarage commences a long and uninterrupted descent of about a mile and a half, beginning with one in sixty, increasing to one in twenty-five; then a short piece of one in forty-five, increasing to one in thirty; and at Roll's-farm becoming one in twenty-five, and continuing about the same rate to the bottom of the hill, which is little above the valley of the Roding.

It will be seen, from the preceding glance at the levels of the existing road, how very inferior it is to a line which might be traced alongside the river, instead of passing over the high ground of Wilcox-green and Chigwell. An excellent line of road might be traced from Snaresbrook-farm, where it should leave the present road, descend very gradually the slope of the Roding valley, passing between Ray-house and Ray-lodge, and crossing the river about opposite Monkham, or Lord's Bushes, and then sweep round on the east side of the river, keeping within a distance of twenty or thirty chains, and passing between the stream and Wolston-lodge, and might join the present road between the twelfth and thirteenth mile from London.

Between Abridge and Chipping Ongar the road is laid out more in accordance with the natural requirements of the country, although there are several spots where great improvements would be made by trifling deviations.

THE CHELMSFORD ROAD.

The next in order is the great Chelmsford road, which also passes out of London through Bow and Stratford, and continues on through Great Ilford, Romford, Brentwood, and Ingatestone, to Chelmsford, where it divides into two branches, one of which passes by Braintree and Halstead to Bury St. Edmunds, and thence by Thetford to Lynn, and various other parts of the Norfolk coast; while the other branch goes on by Witham, Colchester, and Ipswich, to Norwich, where again numerous other roads diverge to Cromer, Cley, Wells, and other sea-ports.

It is remarkable, that this road consists of a series of nearly straight lines from one town to another, the bends taking place at the towns, while the intermediate parts are straight. Thus, from London to Bow is straight; at Bow, the road bends more to the north, and is straight to Stratford—there it bends again to the east, and is nearly straight to Romford, seven miles: at Romford, it bends again to the north, and is nearly straight to Brentwood, six and a half miles; there it bends still to the north, and continues nearly straight through Ingatestone to Chelmsford, distant twenty-nine miles from London. This road is closely accompanied all the way to Ipswich by the Norwich branch of the Eastern Counties railway. The railway keeps on the north side of the road for about eight miles out of London, when it crosses to the south side, about a mile beyond Ilford, and proceeds nearly parallel as far as Brentwood, where it makes a remarkable curve to the south-east, in order to gain lower ground at that summit, and then continues again parallel to the road, as far as Widford, about a mile south of Chelmsford, where it again crosses to the north side of the road, and so passes Chelmsford on the west or north-west side of the town. The engineering difficulty of passing over so low a level as that of the Chelmer, on the east side of the town, is supposed to have dictated this deviation to the north-west. There is, at present, an extensive viaduct over the Cam, above the town, and this work would, of course, have been much more

serious, if constructed over the low level of the Chelmer, on the east side. Without this supposition, it is not easy to conceive why that side of a town, possessing a navigable communication with the sea, should be deserted for the other side, where no such facility exists for transverse communication.

This road, as far as Brentwood, eighteen miles from London, may be said to pass up the valley of the Thames, crossing the following feeders of that river; 1st, the Lea at Bow, three miles from its mouth; 2nd, the Roding at Ilford, about four miles from its mouth; 3rd, the Bourne-brook at Romford, about five miles from its mouth; 4th, the Ingreburn-brook, three and a half miles north of Romford, about eight miles from its mouth. All these streams, and a few intermediate ones, also crossed by this road, flow into the Thames, and their mouths, of course, are the points of junction with that river. The country through which the road passes is very flat from London to Ilford, seven miles: the road then between Ilford and Romford rises into a somewhat higher country, skirting the southern slope of Hainault-forest, and might perhaps be improved by a diversion southward, in some part of this length.

After crossing the Bourne-brook at Romford, the road ascends to a summit opposite Hare-hall, and then descending, crosses a feeder of Ingreburn-brook, and runs parallel for about a mile with the brook itself, which it crosses at Pitwell-bridge, and then takes the course of another of its feeders, as far as Brentwood; here is the summit of country which divides the waters flowing to the Thames, from those which flow in a north-easterly direction into the Blackwater. One of the principal streams of the Chelmer rises about a mile south-east of Brentwood, and flows nearly in the direction of this road to Chelmsford, where it joins the Chelmer* in its course to the Blackwater at Maldon. The road north of Brentwood passes down the valley of this stream, crossing numerous tributaries which flow in a south-easterly direction, and thus affording an example of that very common case in which a road passes in the direction of a river-valley, and crosses all the secondary valleys and intervening ridges. After crossing the Cam and the Chelmer at Chelmsford, the road passes on through a more level country to Witham and Colchester.

* The Chelmer navigation communicates at the port of Maldon with the Blackwater, an arm of the sea.

THE BARKING ROAD.

The next in order is called the Barking road, beyond which place it is continued on through numerous small towns and villages in Essex, till it reaches Southend and Great Wakering, being there stopped by the line of the eastern coast. This road owes its elevation to the rank of a main line of turnpike road to a comparatively recent date, and consists of a number of short pieces of road joining a series of small towns or villages, all united together, the gaps being made up by new pieces of road, and the whole formed into one continuous line. We may hence expect to find that its course is somewhat circuitous; and accordingly, although the country is nearly quite flat throughout, we find it bends at every group of houses, into the direction of the next group lying in anything like the proper direction. This is remarkably the case east of Rainham, twelve miles from London, beyond which place the road is a complete series of zigzags. This road passes out of London through Limehouse, and proceeds to Rainham, through Plaistow and Barking. In all this part, it lies entirely in the valley of the Thames, barely skirting the high ground which adjoins the marshes, but lying more immediately in the marshes themselves, and so crossing, at moderate elevations, the various streams which debouch into the Thames. Beyond Rainham the road passes on through Wennington, Aveley, and Stifford, making a considerable bend at Wennington, in order to keep clear of the marsh of that name.

THE DOVER ROAD.

Having now completed one-fourth of the circumference round the metropolis, namely, a quadrant from its meridian to the river Thames, which flows nearly towards the east, we shall next take the first important road which occurs south of the river; namely, the old Canterbury and Dover road. This famous road, so well known, and so much used before the present South-Eastern railway became the great highway to the continent, boasts of a very high antiquity. Not only is part of this road mentioned by Shakspeare,* but it is known that other parts of it were the work of the Romans, and formed the great line of way called the Wat-

* Gad's-hill, opposite the village of Higham, is the scene of the robbery of the Sandwich carriers.—See Shakspeare's play of Henry V.

ling-street, leading from London to Canterbury. This road proceeds out of London from the Elephant and Castle, where the first part of it is called the Old Kent road, and the Dover road. It then proceeds through Deptford, and passing at the back of Greenwich-park, crosses Blackheath, and passing over Shooter's-hill, goes on through Bexley and Crayford, to Dartford.

The part of the road comprised between Deptford and Dartford is very hilly; and though geographically located in the valley of the Thames, yet it derives very little advantage from this, being situated in a high and hilly tract of country, which closely approaches the river at Greenwich, Woolwich, and Erith; and the road keeps high up on this elevated ground, crossing the various streams not far from their sources. The part between Greenwich and Dartford being quite straight, was probably part of the old Watling-street, and being designed by the Romans essentially for military purposes, was carried by them at such a high level, as to command the adjacent country, in order that it might afford sites for observing the motions of their enemies, and cause the earliest intelligence of a rising or surprise to be circulated with the utmost rapidity from one station to another.

It is impossible to review here all the modern interests that may make it desirable to preserve the road in its present direction; but assuredly, as far as levels and the physical features of the country are concerned, the road is a very bad one, and far inferior to one which might be formed by Woolwich, Erith, and thence across the Dartford-marshes, to join the present Dover road at the village of Greenhithe, about two miles beyond Dartford. Such a road, which might either be made within the marshes, or skirting the rising ground all the way, would be just one mile longer than the present road; but this excess of distance would be amply compensated by the improved levels, and consequent decrease of draught for the horses.

It is remarkable that the next length of this road, namely, between Dartford and Rochester, is entirely deviated from, by the modern road which passes round by Greenhithe, Northfleet, Gravesend, Chalk, and Gad's-hill, till it falls again into the Roman road at Strood. From Dartford to Strood, by the old Watling-street, which is nearly straight, and may still be traced, with the exception of about a mile at Swanscomb-park, the distance was eleven

miles, while the distance by the present road is exactly twelve miles; and here again the distance is as amply compensated as it would have been by a deviation between Greenwich and Dartford. It may be worth notice, that Gad's-hill, the name of a spot already referred to as used by Shakspeare, is on the deviated road between Gravesend and Strood, showing that in his day the traffic was carried on in the same route as at present. This point of Gad's-hill is on the Higham ridge of high ground, through which the Thames and Medway canal is carried by a long tunnel, about a mile east of Gad's-hill.

After crossing the Medway at Strood, and proceeding through Rochester and Chatham, the road proceeds in a perfectly straight direction through Rainham and Milton, by Sittingbourne and Faversham, to Canterbury; the whole of this part being the same road as that used by the Romans, under the name of Watling-street.

The following notes of the gradients on this road, between Deptford and Dartford, will show how much has been sacrificed in order to obtain a straight line: the ascent from Deptford to Blackheath is at first one in seventeen; opposite a new church on the north side of the road, one in fourteen; a little further on, one in eleven: rounding off again to one in fourteen; and so continuing nearly to the Green-man inn.

The ascent of Shooter's-hill, at one hundred yards west of the eighth mile-stone, is one in eighteen; at fifty yards west of ditto, one in eleven; at the mile-stone, one in eleven; the hill then rounds off gradually to one in eighteen; and so continues for some distance. The descent from Shooter's-hill towards Bexley soon becomes one in sixteen, and increases to one in thirteen; at fifty yards further on, one in eleven, and so continues for several hundred yards. By degrees, it becomes one in thirteen, and, near the bottom of the hill, slopes off to one in twenty-two, and so gradually diminishes. Even these gradients at Shooter's-hill have been attained by a considerable cutting on the west side, which has been carried westward to embankment, to raise the foot of the hill. The material is probably plastic clay, which has slipped to a considerable extent.

These disadvantageous gradients might all be avoided by taking the road by Woolwich, and so along the marshes of Plumstead to Erith, as before pointed out. The road

through Lee, Eltham, and Bexley, which falls into the Dover road at Crayford, is also very superior in point of levels, as it entirely avoids both Blackheath and Shooter's-hill, and the access in length is inconsiderable.

THE MAIDSTONE ROAD.

This road passes out of London, like the last, by the Kent road and Dover road; out of which it branches at Deptford, and continues by Lee and Eltham, Footscray, Farningham, and Wrotham, to Maidstone, where it divides into two lines, one of which goes on to Hythe, Folkstone, and Romney; while the other takes a circuitous course to Tenterden and Rye.

From Deptford nearly to Eltham, this road follows the course of a branch of the Ravensbourne. At Eltham, it turns suddenly almost at right angles towards Footscray, passing over a summit, and descending to the level of the Cray, at the latter place. From Footscray, it passes on in a south-easterly direction, and crossing another summit, descends at Farningham to the level of the Darent. From this place the road rapidly ascends into an elevated chalk district, by Hever-farm, Portobello, and the Horse and Groom, and then rapidly descends into Wrotham; and thence on through a tolerably flat district of country, lying between the chalk escarpment and the green-sand range to West Malling and Ditton, and thence to Maidstone.

The descent at Wrotham must be very steep, and although a little artifice has been resorted to with a view of increasing the length of the descent, and so reducing its steepness, this has not been sufficiently carried out; and this passage of the chalk range consequently remains a highly objectionable feature in this road. If the road had now to be made, it is probable that a very different course would be decided on; and the modern engineer would certainly look for some natural pass through the chalk, and if he could find no river passing through it from the south, would next seek some spot where a great depression existed, indicating the probability of some ancient rush of waters having formerly taken place there. Nothing of the kind has been done here; the passage at Wrotham appears to be a forced and unnecessary one, neither judicious nor expedient, and quite inconsistent with the most ordinary and common-place of the rules applicable to such a case. Nor shall we have

to search far for such a gap in the chalk, for Maidstone actually stands on the Medway, which flows northward completely through the chalk by Rochester and Chatham.

He would probably, therefore, carry his road straight up the valley of the Medway, to Cuxton, where he would cross it, then continue it by Nursted and Longfield to Sutton-at-Hone, where he would cross the Darent, using where practicable pieces of existing road which lie nearly, or quite, in the proper direction; and thence in a straight line to Footscray, making the distance from Footscray to Maidstone twenty-three miles, exactly as at present, with the advantage of intersecting a much more level country, and so obtaining a better road.

The principal branch of this road proceeds from Maidstone to Langley and Sutton Valence, where it crosses the green-sand formation, and then proceeds by Headcorn through the wealden district of Kent.

The gradients on this road are tolerably good, until it reaches the chalk district. The principal hill is at Eltham, where the inclination on each side does not exceed one in twenty.

ROADS FROM LONDON TO TUNBRIDGE.

There are two roads branching out of the Maidstone-road last described, which lead to Tunbridge. The first of these commences two miles north of Wrotham, crosses the chalk range at Old Terry's Lodge, and passes by Ightham and Shipborne to Tunbridge. This road is liable to the same serious objection as the one by Wrotham, namely, that it crosses the chalk where no natural gap nor depression exists, and that within a mile of the other crossing at Wrotham. The other road commences at Farningham, and passes up the valley of the Darent by Lullingstone, Eynesford, Shoreham, and Otford; joining the real London and Tunbridge road at Maidstone. This road passes through a very easy country, and is laid out on the sloping ground of the valley of the Darent; yet although every facility is afforded for making a road almost practically level, and with no inclination steeper than would be requisite for good drainage, it does not appear that the natural advantages of the ground have been followed in a judicious manner, although there is no steep inclination in climbing over the chalk, as at Wrotham, or Old Terry's Lodge. We come lastly to the so-called direct Tunbridge-road, which although shorter than either of the others, by Ightham or Otford, is still

made very circuitous by a great number of waves and bends, for which it is usually difficult to conceive any adequate reason.

This road commences out of the last described, between Deptford and Lee, and following the course of the Ravensbourne river, passes through Bromley, and on to Bromley-common and Farnborough. This latter place is situate on a ridge which nearly ranges with the sources of the Ravensbourne and the Cray, and the country here becomes very irregular in its formation, the valleys and ridges assuming various directions, and presenting serious difficulties to any road or railway passing across them. This continues as far as the summit of the chalk, nearly to the Star inn, opposite Chevening, a distance of about five miles in a straight line from Farnborough.

The road, however, owing to its numerous bends and curves, measures about six miles between these points. At the Star, it descends, by a circuitous course, to the comparatively low country between the chalk and the green-sand, and then ascends by Riverhead and Sevenoaks, till it reaches the summit of the sand range, at the south corner of Knole-park, where it rapidly descends this second range, and passes on through a tolerably level country to Tunbridge.

The road here separates into several branches, one of which proceeds by Tunbridge Wells and Mayfield, to Pevensey and East Bourn. Another goes by Lamberhurst, Robertsbridge and Battle, to Hastings; and a third goes by Lamberhurst and Sandhurst, to Rye.

ROADS FROM LONDON TO LEWES.

The first of these, by Westerham, Edenbridge, and Hartfield, is identical with the Tunbridge road, as far as Bromley-common, where it takes a more southerly direction than the Tunbridge road, following closer the valley of the Ravensbourne, up to Keston-common. At Keston village, the road makes a great angular projection westward, in order to avoid Holwood-park, and then enters the same elevated irregular chalk country as that already described between Farnborough and Chevening. The bends on this road are also very considerable between Keston and Betsom's-hill farm, the summit of the chalk ridge. From Keston to Bradfield, about one mile and a half, it passes very obliquely over a projecting tongue of the chalk, and then there is an attempt to take advantage of one of those long, and some-

times straight *coombes* of the chalk, which have been hollowed out by ancient currents of water. This *coombe* runs out, as it is called, before coming to the summit at Betsom's-hill, so that it forms no gap or depression in the chalk; and it does not appear, even where the *coombe* is a distinct and decided hollow, that the road has been laid out with any remarkable judgment. The road descends from the high chalk country at Betsom's-hill, and passes on by Westerham to Westerham-common and Cockham-hill-common, the summit of the sand range, which it penetrates in the same bold manner as it has already done with the chalk; and having arrived in the wealden district, proceeds through a tolerably flat country, by Edenbridge and Cowden, on to Hartfield, and by Little Horsted, to Lewes.

The other road to Lewes is identical with the road to Brighton, (which will presently be described,) as far as Riddlesdown, about thirteen miles from London, where it diverges to Godstone, passing over a more favourable district of the chalk than those which have lately been noticed. The chalk summit is passed about a mile north of Godstone, at a point where there is a considerable depression. The road then proceeds through the village of Godstone, on to Tilburstow-hill, which it crosses, and which is composed chiefly of sand. It then passes on through rather an elevated and irregular part of the wealden district, by Blindley-heath, Frogwood-heath, and Felbridge, on to East Grinstead, whence it goes on to the west side of Peppingford-park and Sheffield-park down the valley of the Ouse, to Lewes.

ROADS FROM LONDON TO BRIGHTON.

The first of these is the old road through Croydon, which leaves London by the Elephant and Castle, and, after passing through Croydon, proceeds along Smitham-bottom, up to Merstham, where it intersects the chalk summit, and then goes on, by Red-hill and Earl's-wood-common, to Horley and Crawley. This is the wealden district, in which the road continues till it meets with the chalk range of the South Downs, which it ascends at Clayton, and thence passes down to Brighton.

Most of the roads we have lately been considering have passed southwards out of London, either up valleys leading them on to the elevated heights of the chalk formation, or

over comparatively low tracts, sloping gradually upwards to the chalk, and have experienced no difficulties until they reach the irregular *coombes*, or *broad furrows*, with their intervening ridges, which everywhere distinguish the chalk district on the south side of London. The *coombes* themselves are usually filled with deposits of flint gravel, the debris of chalk, much mixed with the actual matter of chalk, while the elevated ridges between are usually composed of chalk itself. The beds of flint gravel, intermixed here and there with chalk wash, frequently overlie the edges of the plastic clay; and the hollow points, where they cease and where the clay commences, are usually the sources of streams, which flow over the plastic clay into the Thames, which drains the whole district.

The Ravensbourne and the Wandle are the principal streams which rise in this way in this part of the country; and it is remarkable that there is a considerable breadth between these rivers, and that all the intermediate country is too high to be penetrated by any but secondary streams, or feeders, of these two principals; that no stream of any consequence goes through it to the Thames; and, in fact, that it embraces no streams whatever except those which arise from the elevated strata of the district itself, and which are quite unconnected with the extensive chalk country lying beyond it.

The country drained by the Wandle and the Ravensbourne is of a triangular shape, the apex being at Selhurst-wood, about a mile north of Croydon, where the sources of the eastern branch of the Wandle and the most western branch of the Ravensbourne are within a quarter of a mile of each other. These two streams take a circuitous course round the high district in question, and diverge so far from each other that the distance from the mouth of the Wandle, at Wandsworth, to that of the Ravensbourne, at Deptford, is not less than eight miles in a straight line. The high country lying within these limits includes Clapham-common, Brixton-hill, Herne-hill, Dulwich, Peckham Rye, Nunhead, New Cross-hill, Brockley, Forest-hill, Sydenham-hill, Dulwich-common, Streatham-hill, Upper Tooting, Streatham-common, Upper Norwood, Penge-common, Beggars'-hill, &c. The district which embraces these spots must be exceedingly well known to those at all acquainted with the country round London; but it may not at the same time have attracted general observation that, with the exception

of the Brighton road, now about to be described, and which lies rather on the eastern slope of the high ground, there is no main road leading through it; and that the distance between this road and the Bromley road last described is at no place less than four miles; and that at Bromley itself the distance between the two roads is upwards of six miles.

It is true that there are many roads in most parts of the district here referred to, leading to all the numerous places above mentioned; but none of these are main roads, nor does any of them ever form the road from the metropolis to places lying beyond the elevated district in question.

The Brighton road, leaving London by the Elephant and Castle, and passing to Croydon, through Brixton and Streatham, passes, as we have said, through this district, but quite on the east side of it, where the elevations are much more depressed than in the more central parts by Norwood, Sydenham, and Forest-hill. In fact, the rise from St. Matthew's church, Brixton, up to Brixton-hill, and on to Streatham-hill, is the most considerable one between London and Croydon. The ground at Streatham-common, although high, is tolerably level; and immediately beyond the common commences a comparatively new piece of road, three miles long, and almost perfectly straight the whole way into Croydon; so that upon the whole, the Croydon part of this road may be termed tolerably perfect, with reference to its selection and design. It may be added, that though not quite straight between the Elephant and Croydon, as it bends at Streatham to the extent of a mile and a half west from a straight line, yet this appears judicious, as a much lower country is thereby intersected, and the ascent is much less than it otherwise would be. The ascent from the Elephant to Croydon is about 140 feet; and on any other route intended to shorten the length of the line, it is probable that in several parts the country would attain a greater height than the level of Croydon, so that there would be a loss of power in the unnecessary ascent.

Beyond Croydon this road passes up an extensive *coombe*, or hollow in the chalk, termed Smitham-bottom, winding to a trifling extent, to accommodate itself to the irregularities of the ground. The Brighton railway passes at several places so close to the road, that diversions of the latter have been made to keep it clear of the deep cuttings and spoil-banks of the railway. In passing the Merstham summit, the railway goes through a tunnel more than a mile in

length, with cuttings of great depth at each end. These are rendered necessary by the comparatively flat inclination of twenty feet per mile, which has been adopted for the railway on both sides of its summit, whereas an inclination of 176 feet per mile on the road will about correspond with twenty feet per mile on the railway. Descending from Merstham, the road passes across the flat district of the gault and upper green-sand to Red-hill, where the soft sand has been cut through, and enters Earl's-wood-common, the edge of the wealden district. From this place, it continues through a tolerably flat country, and in a tolerably straight direction, till it again encounters the chalk at Clayton, near Brighton.

The other road to Brighton, commonly called the Sutton road, passes out of London by Clapham, over Clapham-common, and then proceeds, by Tooting and Mitcham-grove, to Sutton. Hence it takes nearly a straight course across the chalk to Banstead-downs, passing over Banstead-heath and Walton-heath, whence it bends considerably to the east, in order to gain a somewhat more favourable point for crossing the chalk. About a mile north of Reigate, the descent from the chalk commences, the road doubling back towards the west, in order to diminish the steepness; and when about half way down, passing for some short distance quite in a westerly direction, and then making straight for Reigate, which it enters rather on the west side of the town. The road emerges from Reigate rather on the east side, and then skirting Lord Somers' park, passes by a deep cutting at Cockham-mills, through the sand ridge, and then proceeds across the wealden district in nearly a straight direction over Hookwood-common, to Povey-cross, near Horley, where it falls into the other Brighton road, at the distance of twenty-seven miles from London.

The first part of this road, from Kennington to the crossing of a branch of the Wandle at Tooting, lies still more to the westward, on the slope of the high country of Brixton and Norwood, than the other Brighton road. Clapham-common is rather an elevated point, but all the inclinations are very moderate as far as the street of Sutton, where the ascent is steep. Here also commences the true chalk country, which continues to ascend over the Downs and over Banstead-heath and Walton-heath. Between Sutton and the point of descent from the chalk, the road bends considerably to the west, in order to take advantage of a more favourable surface.

ROAD FROM LONDON TO WORTHING.

THIS road diverges from the Sutton road last described, at Tooting, and passes by Merton-abbey, Mitcham, and Morden; thence in a straight line nearly to Ewell, then through Ewell and Epsom, Ashtead and Leatherhead. Here it enters the celebrated vale of Mickleham, and passes up the valley of the Mole, through the village of Mickleham, by Burford-bridge, to Dorking. Then it proceeds through the wealden country, over Holmwood-common, by Capel and Warnham, to Horsham. From this place it goes on to West Grinstead, and at Storrington intersects the chalk of the South Downs, passing through a deep cutting, and then descending to Worthing. About a mile south of Tooting this road makes an extraordinary bend to the westward, whereby in a single mile the length is increased to the extent of thirty chains. This bend was probably made to avoid the grounds of Merton-abbey, and probably because the straight line would pass across a swampy, imperfectly-drained tract of ground, bordering the Wandle, from Mitcham to Terrier's-bridge. This land is now, however, in a widely different condition, being in a state of high cultivation; and, upon the whole, there does not appear to exist any obstacle to straightening the road at this part, so as to effect a saving of thirty chains, or three-eighths of a mile, in distance. From the village of Mitcham, the road is nearly straight to Ewell, at a little more than thirteen miles from London. In this part, the road passes over a clay and gravelly district lying on the chalk, which is easily reached, between Ewell and Mitcham, by boring a few feet, or yards, in depth. From Ewell to Epsom the road is just on the verge of the chalk country, and half a mile beyond Epsom it passes over the common of that name, which, being rather high ground, consists, for a considerable depth, of clay. Then it passes on to Ashtead, between which and Leatherhead it again intersects the chalk. At Leatherhead the road turns nearly at right angles, and pursues a southerly direction along the valley of the Mole.

This river, the principal streams of which rise on the north sides of Tilgate and St. Leonard's-forest, after intersecting the wealden country in a very circuitous direction, and receiving innumerable small tributaries, which flow into it from every point of the compass, penetrates the green-sand range in an oblique, north-westerly direction,

near Betchworth, and flowing round the grounds of Betchworth-castle and under Box-hill, assumes a northerly direction, and completely passes through the chalk by Burford-bridge, and winding round Norbury-park, passes on to Leatherhead, and so on, by Stoke d'Abernon, Cobham, and Esher, into the Thames at East Moulsey.

The vale of Mickleham is probably, with the exception of the gap at Guildford, the most favourable of all the passes through the range of the North Downs chalk-hills. Of course those passes through which rivers flow are superior to those mere depressions in which no river or stream has its course. Premising this, the only passes east of Dorking are those of the Darent, which goes through the chalk north of Sevenoaks, and the Medway, which goes through Maidstone northward, to Rochester and Chatham.

Now both these latter are much inferior to the Dorking pass, because opposite to each is a very high part of the green-sand range, which opposes the carrying of a road or railroad through them, except in a very circuitous direction. Thus the Darent, which flows northward from Sevenoaks, nowhere penetrates the green-sand, the whole of which range at the south of Sevenoaks, and for miles on each side, is very high, and presents formidable difficulties. The Medway again penetrates the green-sand about five miles west of Maidstone, which makes this passage out of the question for roads going to the south or south-east, which, accordingly, cross the green-sand where there is no gap at all. From these considerations it follows that the Dorking gap is the most favourable of all those lying to the east of it, while on the west side there is only the Guildford, which is under nearly similar circumstances.

Between Leatherhead and Dorking the road does not follow the windings of the river, but adopts a tolerably straight course, yet has no inclinations of such steepness as to render any deviation desirable. In passing through the town of Dorking, the road is deflected about half a mile further to the west, and then proceeds to Holmwood-common, where it passes over the green-sand range at a spot where it is much depressed, and proceeds on, as before described, through Capel and Warnham, to Horsham.

ROADS TO GUILDFORD.

One road from London to Guildford follows the same course as the last described, as far as Leatherhead, and in

fact continues that road in a straight line through the town, where it crosses the river Mole, and proceeds by Great Bookham, Effingham, West Horsley, East and West Clandon, and Merrow, to Guildford. The other road passes out of London, through Battersea and Wandsworth, goes over Putney-heath, skirts the south-east side of Richmond-park, passes over Kingston-hill, and so down into Kingston. After passing through the town for three-quarters of a mile, nearly in a westerly direction, it proceeds close alongside the river Thames for nearly two miles, then goes over Ditton-marsh, and through the village of Esher. It then skirts the west side of Claremont-park, goes on to Cobham-street, passes over Cobham-common and Wisby-common, and goes on by Ripley, Threefords, and Gasding-hill, to the east side of Stoke-place park, and on to Guildford, which it enters at the same spot as the road from Leatherhead. The distance from London to Guildford by the first of these roads, namely, that through Epsom and Leatherhead, is thirty-two miles, and by the other, or the Kingston road, the distance is twenty-nine miles.

The Leatherhead road, in its passage from Leatherhead to Guildford, passes over the chalk country in a more oblique direction than any of those we have before considered. Both these towns may be taken to be situate on the chalk, Guildford being about ten and a half miles west of Leatherhead, and four miles south of it; and the road we are now examining connects the two places by forming the hypothenuse of a right-angled triangle, whose base and perpendicular are respectively ten and a half and four miles. It lies nearly at the head of the water-bearing valleys which open from the chalk of this district, and range in a northerly direction, and as it approaches Guildford almost defines the head or summit of the highest *combes*.

It is scarcely necessary to observe that the Thames is the general drain of all this district, and receives into its ample stream all the water rising from this as from every other part of the North Downs; but the secondary rivers, which more immediately drain the section of chalk country between Leatherhead and Guildford, are the Wey and the Mole; and one or other of these rivers receives all the small tributaries which flow down the *combes* of the chalk.

It is obvious that a road in the situation of the one here described, alternately intersecting the hollows in the chalk surface and the ridges which separate those hollows, in

order to be the most perfect in its levels, should assume a wavy or bending direction, approaching the summit of the chalk range in crossing the hollows, and receding from it in crossing the ridges. This is, in fact, a similar case to that of a road passing up the actual valley of a river, and crossing alternately to tributary streams and the ridges which separate them. This mode of laying out has obviously not been followed in all cases in the road before us, but it is unnecessary to point out that it always ought to be followed where circumstances of another nature do not imperatively require an opposite course.

The second, or more direct road to Guildford, passes at first over a flat country, through Lambeth, Battersea, and Wandsworth, seven miles from London, being nearly on the extreme western verge of the district already described as drained by the Ravensbourne and the Wandle. At Wandsworth the road begins to rise, passing over the north-west corner of Wimbledon-park, and attaining its summit on Putney-heath. It then descends to cross a small stream which rises on the chalk at Cheam, flowing by Pylford-bridge and Combe-bridge, forming successively, but on alternate sides, the boundary of Wimbledon-common and Richmond-park, and continuing by Peace-bridge at East Sheen, and falling into the Thames on the east side of Barnes.

Beyond this stream, which is crossed at Bayeley-bridge, the road goes along the south-east side of Richmond-park, passes over some high ground called Kingston-hill, and enters the town of Kingston at the east end. After passing through the town in a westerly direction, for rather more than half a mile, it diverges from it at the west end, and proceeds for a mile alongside the river Thames as far as Thames Ditton, where the Thames bends to the north-east, while the road pursues the same south-westerly direction as before. From Thames Ditton to Cobham the road may be described as lying in the valley of the river Mole, being nowhere more than a mile distant from that stream, and often approaching more nearly to it. The surface of this district is thrown into irregular shapes by numerous elevations, sometimes appearing as continuous ridges, and at other times mere conical hills—consisting of fresh-water sands deposited on the London clay, and ranked by geologists of contemporaneous age with the extensive sands of Bagshot and Frimley heaths. These numerous detached

elevations of sand have probably been continuous over this part of the country, but the formation has perhaps been washed away, so as to present at the present day only the form of numerous isolated hills, ridges, and elevated plains. This road, where it borders the Mole, passes over several of these patches of sand, as at Esher, Claremont-park, Esher-common, Old Common, near Cobham, &c. The road is tolerab.y straight between Thames Ditton and Cobham, but might probably be improved by sweeping through the valley of the Mole in a more central direction, instead of keeping so far on the east side of it, and this without any sacrifice of distance.

Between Cobham and Ripley the road passes over the sandy district of Cobham-common, Red-hill, and Wesley-common, which divides the river Mole from a branch of the Wey that flows into it at Ockham-mill, and in fact forms also the water-shed between the two main streams. Immediately south of Cobham there is a remarkable deviation made in the straight direction of the road, by which, in a length of two miles, an increase of distance is made of nearly half a mile. Thus, instead of passing from Cobham-street by the side of the Mole, and crossing it at a point due west of Cobham-court, and shortly after entering Ockham-common a little north of Catley-farm, and then ranging in a straight line for Bodystone-hill, the road suddenly turns to the north-west at Cobham-street, immediately crosses the Mole, and passing round Pains-hill-park goes over Common and Red-hill, where it again bends into a more southerly direction, and joins the straight line just described a little north of Bodystone-hill.

This serious injury to the road appears to have been inflicted to suit the convenience of the owners of several parks and superior mansions situate around the borders of the commons and in the valley of the Mole. Beyond Ripley the road encounters no more of the sand-ridges before spoken of, and passes gradually off the clay on to a country where the chalk is near the surface. From Ripley to Guildford the road occupies the valley of the Wey, is tolerably direct in its course, and no improvement of any consequence suggests itself.

The two main roads from the metropolis which have been described as meeting at Guildford, there separate and diverge in various directions. First, there is the Farnham road, which passes in a singular manner along the very

highest ridge of the chalk, along the actual axis of the Hogsback, having of course a serious ascent to encounter in emerging from the level of the Wey at Guildford, and an equally serious descent from the chalk, about two miles east of Farnham. This road then goes on by Alton to Winchester and Southampton, while another branch of it, diverging at Alton, passes by West Meon and Droxford, down to Fareham and Gosport. Secondly, the Godalming road passes nearly south, and there diverges into three branches, one of which passes by Bramshot and Petersfield, down to Portsmouth; another goes through Haslemere and Midhurst to Chichester and Selsea Bill, while the third goes to Petworth, and there sends off one branch to Chichester and another to Arundel. The third road out of Guildford is the Wonersh-road, which passes on through Aldfeld and Pulborough to Arundel, Littlehampton, and Worthing.

THE STAINES, OR GREAT WESTERN ROAD.

Of all the roads which pass out of London, the Staines road is the most level, and with one exception the straightest. In the days of coaching, before the introduction of railways, this road was remarkable for the vast amount of traffic which passed, and this notwithstanding it only formed one of the routes to Reading, Bristol, and the West of England; most of the coaches at that time going to Reading by Colnbrook and Maidenhead, which, although a longer road, possesses a much larger population than that which adjoins the Staines road. The traffic, however, is still very great on the first eight miles out of London, namely, as far as Brentford; the whole of this space being at all times covered by innumerable light vehicles, mixed up with heavy traffic of almost every description.

This Staines road occupies an entirely different district from those we have latterly been considering on the south side of the metropolis. These have generally passed over a high clay district, which appears in far distant ages, long before our mundane chronology attempts to record events, to have withstood the rush of waters which have excavated the valley of the Thames. Opposed to these, on the north side of the Thames, we have the high ground of Hampstead, Highgate, and part of Hornsey, where the fresh-water sands —a much more recent deposit than the clays of the south— have not been denuded, but have either formed the banks

of the estuary or islands which have never been submerged beneath its waters. Supposing these sands on the north side to have bounded the estuary, we find its breadth, from Battersea to the foot of Hampstead-hill, to have been about five miles; from Upper Holloway to the rise of Brixton-hill, about six miles; from the rise of Epping-forest to Greenwich, about four miles and a half, and so on, the breadth varying for some distance from four to six miles. Although the channel is thus contracted eastward of London, there seems on the west side to have been a great expansion; for, while on the south the boundary appears to have been the high lands which nearly follow the circuitous course of the river from Windsor by Staines, Chertsey, and Kingston, the northern boundary seems to have swelled out wider and wider by Uxbridge, Ruislip, Pinner, by Stanmore, Highwood-hill and Southgate, and then to have trended southward by the side of that high tract which bounds the Lea on the east side. According to this view, Harrow-on-the-Hill and the sand-hills of Hampstead and Highgate would have been islands in this great lagoon, whose waters would sweep round and enclose them; but whether those solitary hills now standing, and composed of clay, were submerged or not, is difficult to say. With respect to the sand-hills, it is clear they have never been submerged.

The road we have now to speak of lies entirely within this ancient lagoon, the breadth of which, from north to south, say from Pinner to Chertsey, was not less than fifteen miles; and it lies so clear of all high lands and supposed ancient islands, that it is almost a perfect level the whole way from London to Staines. This road passes out of London by Piccadilly and Hyde-park-corner, and proceeding along the south side of Hyde-park and Kensington-gardens, passes through Kensington, Hammersmith, and Turnham-green to Brentford, and throughout all this distance of eight miles, is lined by an almost uninterrupted succession of houses. From Brentford the road proceeds in a straight line through Hounslow and East Bedfont on to Staines, a distance of sixteen and a half miles from Hyde-park-corner. Throughout this distance, with the exception of some slight bends at Kensington, Hammersmith, and Brentford, the road is practically a straight line.

It has already been stated that this part of the road lies

entirely in the London clay, and is nearly a dead level throughout; we have now, therefore, to examine its extensions beyond Staines. In the first place, there are two roads from Staines to Reading, which we shall distinguish by the terms "Upper" and "Lower" road; these two unite into one a little beyond Wokingham, and form the original old great western road through Newbury, Hungerford, and Marlborough to Bath and Bristol. Second, there is the Bagshot road, which divides at Golden-farmer-hill, a little beyond Bagshot, into two branches, one of which goes down to Farnham, where it unites with one of the roads already described as leading from Guildford through Farnham, Alton, and West Meon, down to Gosport; while the other diverges in a more westerly direction to Basingstoke, Winchester, and Southampton; and at the former of these towns a still more westerly branch leads off to Salisbury, Exeter, and Plymouth, forming the great road into Devonshire and Cornwall.

The upper road to Reading passes through the village of Egham, and immediately begins to rise up to the high ground forming Windsor-park, which is one of those extensive and elevated ridges of sand which we have seen prevailing so extensively in the neighbourhood of the roads to Guildford. This road continues to rise for more than two miles, before it attains the general level of Windsor Great Park, at this spot, which is a little, but not much, lower than the very highest part. It bends considerably towards the north in going through the Park, and intersects the sources of several small streams which flow in a northerly direction into the Thames. Its course through the Park may be defined by the following points:—Bishop's-gate, Park-place, Snow-hill, where the long walk terminates, Watch-oak, near which it crosses the Queen's-walk, and Holly-grove. It then skirts the north-west side of Cranbourn-wood, and, at seven miles distance from Staines, turns at right angles into a westerly direction, and passes over Lovel-hill by the north side of Ascot-place-park, then on to Winkfield and Maiden-green, where it suddenly turns again at right angles into a nearly southerly direction, and passes on to Haley-green and Newell-green, turning gradually into the proper or westerly direction, passing over Cabbage-hill, south of Binfield-park, on to Tippen's-hill. Then it goes south of Ashridge-wood, and shortly after bends into a south-westerly

direction by Toutley-hall on to Toutley-common, where it joins the lower road to Reading, at the distance of seven miles from that place.

The lower road to Reading, although much more level than the upper, is precisely the same length, the distance from London to Reading by each road being about forty and a quarter miles. After leaving the village of Egham, the lower road ascends Egham-hill, and proceeds by Wick-lodge and the Wheatsheaf, down to Cascade-bridge, where it touches the corner of Virginia-water, and crosses a small stream which rises from the sandy strata of Bagshot-heath, Sunning-hill, Ascot and Windsor-forest, and flows into the Thames below Chertsey. Just beyond Cascade-bridge the Reading road separates from the Bagshot road at twenty-one miles from London, the former taking a westerly direction, and the latter pointing nearly to the south-west. From the twenty-first mile, the road proceeds along the south side of Windsor-park through Blacknest and on to Sunning-hill. It then proceeds in a straight line for nearly three miles, passing by Sunning-hill wells, the south side of Ascot race-course, Englemoor-pond, and Martius, soon after which it curves to the north at the crossing of Bullbrook, when it appears, from the shape of this part of the country, it should curve to the south to cross the brook higher up, and proceeds through the village of Bracknal across Priest-wood-common, and on to a place called Golden Acorn. Here the road makes a sudden bend to the south-west, and goes on to Frognall-green, when it bends into a direction north of west, and soon after enters Wokingham. In the town of Wokingham the road makes two bends in opposite directions, then proceeds in a tolerably straight course to Reading.

It appears that the levels of this road might be materially improved between Wokingham and the twenty-seventh mile, a distance of four miles, the twenty-seventh mile being at the western extremity of that straight part which has been already described as commencing at Sunning-hill. This improvement would also effect a saving of distance equal to half a mile in a length of four miles. This road, as far as Bracknal, passes over that sandy district lying between Windsor-forest and Bagshot-heath. Beyond this sandy district the London clay scarcely appears, but the plastic clay is extensively developed between Wokingham and Reading.

The Bagshot road for four and a half miles beyond Staines, namely, to the twenty-first mile, is identical with the road last described. It then proceeds by Shrubs-hill and Broom-hill-hut, over Bagshot-heath by Bagshot-park into the town of Bagshot. It then goes on by Golden-farmer-hill, between Turf-hill and Crawley-hill on to Osnaburgh-hill, near the Military College at Sandhurst, about a mile beyond which, viz. at thirty and a half miles from London, it crosses the Blackwater river, which joins the Loddon a little south of Swallow-field, and flows into the Thames at Wargrave, a little above Henley. Beyond the Blackwater, the road proceeds over a farther succession of dreary wastes and commons, the principal of which are Yateley-heath and Hartford-bridge flats, and passes on through Winchfield and Old Basing to Basingstoke. This road, for a distance of fifteen miles, namely, from twenty-one to thirty-six miles from London, passes almost entirely over dry sandy heaths, in which little has even yet been done to induce cultivation. A great part of this district is perfectly flat, the construction of the road has evidently cost very little, and it is difficult to see where any improvement could be made between Staines and Basingstoke.

The Farnham branch, which separates from the Bagshot-road at Golden-farmer-hill, remains to be noticed. This road proceeds in nearly a straight course to Frimley, where it crosses the Blackwater about two miles higher than the Basingstoke road last described; it then proceeds by Wind-mill-hill to the west side of Farnborough-place-park, near which the South-Western railway crosses it, the Farnborough station being fixed at the crossing of this road. Then the road goes on over Aldershot-heath by Bagman's-castle, crossing the Basingstoke canal at Bow-barge, and proceeding by a place called West-end, touches the eastern extremity of Hungary-hill, and descends by a rather circuitous course to the town of Farnham, where, as already explained, it joins the road from Guildford to Gosport. This road, like the preceding, passes chiefly over a considerable tract of sandy heath, very uninteresting and unvaried in its appearance. Here and there large tracts in the neighbourhood of the road have been planted with fir trees, which will in time ameliorate the hard knotty soil, containing much undecomposed fibrous vegetable matter, which forms the surface of these heaths, while an abundant application of lime, by decomposing and rotting this vegetable matter, will probably

in the course of a few years cause it to bear crops and to be worth cultivation. Its course being tolerably straight, no improvement suggests itself as to the mode in which the road has been laid out.

THE MAIDENHEAD ROAD.

This is another of the roads leading from the metropolis to Bath, Bristol, and the West of England; and as it joins the Staines road at Reading, the extensions beyond that place will apply equally to the road through Maidenhead; it is remarkable also that the length by each road to Reading is about the same. This road leaves the Staines road at Hounslow, ten miles from London, and proceeds in a straight direction to Cranford-bridge, where it crosses the Yedding-brook, a circuitous stream which works several flax-mills, powder-mills, and oil-mills, and flows into the Thames at Isleworth. The road bends into a more westerly direction at Cranford-bridge, and proceeds by Harlington-corner and the Magpies to Longford, where it crosses, in space of less than half a mile, three streams into which the river Coln is here divided, and proceeds on to Colnbrook, where, at seventeen miles from London, it crosses the main stream of the Coln. From Colnbrook the road proceeds in nearly a straight line to Slough, passes over Salt-hill, the scene of Eton Montem, and on to Two-mile brook, where it crosses a very small stream which flows into the Thames at Boveney. From this point the road runs nearly straight to Maidenhead, twenty-six miles from London, after passing under the Great Western railway at the twenty-fifth mile, and a little further on passing over the river Thames. With the exception of the slight rise at Salt-hill, immediately beyond Slough, the whole length of this road from London to Maidenhead may be considered a practical level; it lies for the whole distance in the valley of the river Thames, in a flat, open, and probably diluvial district of country, almost entirely devoid of irregularity. This road is superior to the Staines Great Western road, inasmuch as on that road the low flat country ceases at Egham, eighteen miles from London, whereas the low flat country continues on the other road to Maidenhead itself, twenty-six miles from London. Beyond Maidenhead the road forms a sort of bow, bending to the north between that place and Twyford, thirty-four miles from London, which has the effect of

throwing it into irregular ground at Vines-hill, Stubbing's-heath, Knowl-hill, and other places, where the road skirts an elevated chalk country, which lies between itself and the river Thames, which here makes a great *detour* to the north. The Great Western railway, between Maidenhead and Twyford, is a straight line, and the levels of the road would also be improved by adopting the same course. At Twyford, the road is on a comparatively low level, as it here crosses the river Loddon, at less than two miles from Wargrave, where it joins the Thames. The road continues through a flat district of country from Twyford to Reading. In addition to the traffic passing through Maidenhead to Bath and Bristol, this place formed also a point on the main road through Lechlade and Cirencester to Gloucester and Cheltenham, and the greater part of South Wales. Some of the coaches also to Oxford, and even Birmingham, passed this way, allured into the more circuitous road by the hope of passengers who did not possess the advantage of being located on the great Holyhead road.

THE OXFORD ROAD THROUGH UXBRIDGE.

THIS road leaves London on the north side of Hyde-park and Kensington, keeping parallel to the Staines road as far as Shepherd's-bush, nearly three miles from London. It there diverges into a northerly direction, and passes on, by Acton and Ealing-common, to the north side of the village of Ealing, where the Great Western railway almost touches it. The road then runs parallel to the railway, as far as Hanwell, and passes under it a little further on, namely, at eight and a half miles from London. It then passes on through Southall, over the Paddington canal, at ten and a half miles, by the Adam and Eve and Hayes-end, to Hillingdon. Here it makes a considerable curve to the south-west, to avoid the grounds of Hillingdon-house, and soon after enters Uxbridge, fifteen miles from London. Beyond Uxbridge, it crosses the Grand Junction canal and the river Coln, and continues in a straight course, by Ivy-house, to the west side of the village of Denham, where it bends into a more westerly direction, and proceeds, by Pinnington and Woodhill-farm, to Gerard's-cross-common, a high and open part of the country. Leaving Gerard's-cross, the road proceeds in a tolerably straight course to Beaconsfield, passing on the north side of Bulstrode-park, and south of Wilton-

park, through a high district of country. Beaconsfield is twenty-three miles from London, and the road proceeds from this place in a westerly direction to Holtspur-heath, immediately beyond which it descends rapidly into the valley of the Loudwater, a stream of short extent, but of great commercial importance, from the great number of valuable mills it works. This stream rises from the chalk beyond West Wycombe, flows down a deep valley in a south-easterly direction, sweeps round Woburn-hill, and falls into the Thames half a mile above Cookham. The road proceeds up the valley of this stream, keeping on the east side of it, and passing through the village of Loudwater by Wycombe-marsh and Basonbury to High Wycombe. It then continues, still on the east side of the Loudwater stream, for two miles in a straight line to West Wycombe, passing north of West Wycombe house, a little beyond which it leaves the valley, and bends to the south-west. It then passes by Mice-farm and St. Andrew's, and, bending again, assumes its former north-westerly direction, and goes on, by Ham-farm, the Hut, and Beacon's-bottom, to Stockenham-common, whence it proceeds, through Tetsworth, Rycote, and Wheatley, to Oxford. This road, as far as seventeen miles from London, or about two miles beyond Uxbridge, passes through a flat district of clay, containing some few ridges and irregularities, but not materially varying in its character from that adjacent to the Staines and Colnbrook roads. There is a slight rise at Kensington and Notting-hill, another at Acton, and also at Hillingdon, near Uxbridge. With these exceptions, this first part of the road is tolerably level till it rises on to Red-hill, immediately beyond Denham. From this place to some distance beyond West Wycombe, say from seventeen miles to about thirty-five, the road may be considered to pass over a chalk district, because, although the ridges between the valleys frequently consist of clay or gravel, and sometimes of sand, these are mere patches resting on the chalk, and have generally been denuded from the valleys in which the chalk is exposed. Thus gravel, clay, and sand, are all met with in the furrowed, broken, and irregular country between Uxbridge and the valley of the Loudwater. In this part of the country, it is very common to find the operations of brick or tile-making and lime-burning carried on in the same plot of ground; the clay being dug from immediately below the surface, while the chalk for burning into lime is

procured from a shaft sunk through the clay, varying from a few feet to sixty or seventy feet in depth. The chalk is exposed on each side of the Loudwater valley, as far as West Wycombe. The main continuation of this road beyond Oxford goes on through Witney, Burford, and Northleach, to Cheltenham, Gloucester, and Tewkesbury; while roads branch off from one or other of those towns to most parts of Herefordshire, Monmouthshire, and the southern counties of Wales. Another important road from Oxford passes through Woodstock, Enstone, Shipston, and Stratford-on-Avon, and thence, through Henley-in-Arden, to Birmingham.

ROADS TO AMERSHAM AND AYLESBURY.

The most direct road to Amersham branches out of the Oxford road last described, about a mile beyond Denham, or eighteen miles from London, and proceeds up the valley of the Misbourn stream, which rises from the chalk about a mile beyond Great Missenden, and flows into the Coln a little above Uxbridge. On leaving the Oxford road, the Amersham road rapidly descends into the Misbourn valley, and passing by Oak-end, and on the west side of Chalfont-park, goes on to Chalfont St. Peter, where it crosses the stream, passing over to the east side of it. Thence it continues, by Gravel-hill, Water-hall, and Stoneage-pheasant, opposite to Chalfont St. Giles, which is on the west side of the stream. The road then proceeds, still on the east side of the valley, by New-house, the Hut, Harwood-downs, &c., on to Amersham; just before coming to which it again crosses the stream. This road, with the exception of the abrupt descent on leaving the Oxford road, appears to be judiciously laid out in its progress up the valley; and even this descent it would be difficult to avoid without making an additional line of road, and so joining the Oxford road at the foot of Red-hill, which is little above the level of the stream opposite Denham.

The other road to Amersham is a mile longer than the one just described, and passes over a much more irregular country. It leaves London by the well-known Harrow-road, which may be viewed as a continuation of the City-road and New-road, and, passing through Paddington in rather a crooked direction, crosses the Paddington canal near Westbourne-green, and proceeds on the north-east side of the canal by Kensal-green, bounding there the cemetery of

that name, and crossing at the corner of the cemetery the London and North-Western railway, which here passes under an archway, and where the road is carried over, at the same time that it extends under a corner of the cemetery which it was necessary to preserve intact. The road then passes on over Honeypot-hill, by Holsden-green, near Greenhill-house, opposite which it begins to descend Honeypot-hill, which it never ought to have ascended, and could very easily have avoided. At five miles from London commences the descent, by the road suddenly bending at right angles to the south, from which point it twists round again into its proper direction, till on crossing the Brent near the sixth mile, it again attains the north-westerly course. Before reaching the seventh mile, however, that is, when just opposite Wembly-park, it again totally alters its direction, proceeding to the eighth mile in a course rather south of west, there again changes, pointing now nearly to the north; and after several other bends, curves, and irregular unmeaning gyrations, mounts right up into the High-street of Harrow-on-the-hill. Having attained this elevation, which is a mere isolated ridge, about three miles in length, by an average breadth of a mile and a half, and which sends off streams from innumerable points all round its circumference, the road proceeds along it in the longest direction, and having completely passed through the village of Harrow, descends at the north end of it. The road then proceeds, through the same infinite variety of twists and bends, to Hooking-green and Pinner, which is probably one of the most crooked and irregular villages in England. Beyond Pinner, the road proceeds over Pinner-green, in a north-westerly direction, to Batchworth-heath, a little more than sixteen miles from London. It then passes for a mile and a half on the south-west side of Moor-park, and, crossing the river Coln and Grand Junction canal, arrives at Rickmansworth. Thence it passes on the west side of Rickmansworth-park, which separates it from the valley of the Chess, and then on to the north side of Chorley-wood common. It then passes on to Green-street, where it bends into a westerly direction; is parallel to the Chess, and within half a mile of it, for a distance of a mile and a half, when it twists in several directions, and goes on to Loudhams, within two miles and a half of Amersham. At Loudhams the road assumes nearly a westerly direction, passing on the north side of Beel-house. Then, within one

mile of Amersham, it bends at right angles into a southern direction, and joins the Uxbridge-road to Amersham about half a mile before entering the town. The two roads being here united into one, it continues through the town of Amersham, and proceeds still in the Misbourn valley, passing by Little Missenden and Great Missenden, and then on to Windover, through an open gap in the chalk, and so, with no great variation, to Aylesbury.

This road, between London and Amersham, although about the same length, or perhaps a little longer than the road by Uxbridge, ought to be much shorter, its general direction being much straighter, Harrow and Pinner being actually in the straight line between London and Amersham, and Rickmansworth not more than two miles north of the straight line. On the other hand, the road by Hanwell, Uxbridge, and Chalfont St. Peter, is a complete bow or arc; the first of these places being four miles, Uxbridge being five miles, and Chalfont St. Peter being two miles out of a straight line drawn from Amersham to Cumberland-gate, Hyde-park. The reason, then, of the road being much the straightest in general direction is to be sought for in the innumerable short bends and twists which have been noticed in describing its general course. First, there are the various bends which it makes in going over Honeypot-hill, and the bend at Wembly-park. These might all be avoided, with all the irregularity of ground which the bending, after all, does not appear designed to meet; and, at the same time, half a mile of distance may be saved in four miles of road, by bending it at the corner of Kensal-green cemetery, so as not to cross the railway at all, and carrying it between the railway and the Paddington canal, as far as Apperton, thence sweeping round by a great curve into the present road at the Swan. With respect to the passage over Harrow-hill, this of course is not to be avoided, except at the expense of sacrificing the convenience of the town, which is probably not to be overlooked. It certainly does seem, however, that a more direct course might be taken on leaving Harrow; that between that point and Pinner the road might be shortened; and, particularly at Pinner, that it might be very much improved. From Harrow to Pinner, and indeed nearly as far as Rickmansworth, the road passes over a high country, which although geographically considered as part of the valley of the Thames, yet has lost its valley character, and become the summit from which flow

the feeders of the Yedding-brook and the river Coln. The road might be somewhat shortened by removing objectionable bends between Pinner and Rickmansworth, but perhaps not materially improved in its levels. From Rickmansworth the road passes on for nearly seven miles in a tolerably easy country, which may be termed the valley of the Chess, a stream which rises a little beyond Chesham, and flows through the chalk, by Flaunden and Chenies, to Rickmansworth, where it joins the river Coln. A part of the road between Rickmansworth and Amersham may be greatly improved, and at the same time shortened, by avoiding that great bend which has been before described, at one mile from Amersham. The road should turn off at Loudhams, two and a half miles from Amersham, and curve gradually round into a westerly direction, until it joins the Uxbridge-road at the same point as at present. Thus it would have a much more gradual fall into the valley of the Misbourn than the existing road, and would be fully half a mile shorter in a distance of little more than two miles. The extensions of this road beyond Aylesbury go on in one direction, through Bicester, Enstone, Chipping Norton, Moreton-in-the-Marsh, Broadway, and Evesham, to Worcester, and thence to Leominster, Tenbury, and Bewdley, also to Aberystwith and the central counties of Wales. Another road from Aylesbury leads on, through Buckingham and Banbury, to Stratford, Warwick, Coventry, and Birmingham.

THE ST. ALBAN'S ROAD.

THE road to St. Alban's through Edgeware possesses some interest, because it is the shortest route to St. Alban's and a host of places beyond, and because there is abundant evidence of its having been the work of the Romans, whose skill and sagacity it very strikingly exhibits. It leaves London at Cumberland-gate, and proceeds through Paddington, in one undeviating straight line, as far as Brockley-hill, a distance of more than ten miles from Cumberland-gate. It passes over what is now called Maida-hill, a sloping tract of ground lying west of the Regent's-park, and proceeds by Kilburn-priory on to Kilburn-wells, where it crosses over the London and North-Western railway. It then proceeds through Kilburn-vale, one of those hollows leading up to the side of Hampstead-hill, and passes on by

Shoot-up-hill to the Slade and Lower Oxgate farm. Shoot-up-hill is separated by a depression from the elevated slope of Hampstead-hill, and through this depression the road passes. The Slade and Lower Oxgate farm mark two sources of the river Brent, indicating the road to be still on comparatively high ground. The road then goes on to cross other feeders of the Brent, having their sources higher up in the country towards Fryern Barnet and Whetstone, passes near a few houses called the Hyde, then adopts the valley of one of the principal feeders of the Brent, which rises beyoud Edgware, in fact from the side of Brockley-hill. The road passes through the long street of Edgware and Little Stanmore, and ascends to the summit of Brockley-hill, where was fixed the famous station called *Sullonicæ*. The road then bends somewhat out of its direction, and crosses over an intermediate depression to Elstree-hill, which is only a mile distant from Brockley-hill. At the end of the village of Elstree, the road takes another bend in the direction of St. Alban's, and proceeds in another perfectly straight line to St. Stephen's, one mile from the centre of the town. Beyond Elstree the road passes by Medburn, and then proceeds nearly to St. Stephen's, in the valley of a branch of the Coln, which branch rises from several sources springing from the high ground of Elstree, Brockley-hill, and the neighbourhood. It passes on the west side of Kendal-hall, west of Aldenham-lodge, by Colney-street and Park-street, where it crosses the Coln itself, and then over two small rises in the ground to St. Stephen's. From this point the ancient road probably went on still in a straight line to Verulam, the Roman name for St. Alban's, but now more particularly applied to a part situate on the stream of the Coln, westward of the town. To the part now called Verulam the straight road from Elstree to St. Stephen's directly points, but the present road bends at St. Stephen's, and after again crossing the Coln, rises rather abruptly into the centre of the town.

The levels of this road are favourable, as it keeps a sufficient distance from the high ground on the western side of Hampstead to avoid its irregularity. About two miles further on it begins to ascend, and continues gradually to the summit of the country at Brockley-hill. The road here bends to Elstree-hill, obviously for military purposes, and then gradually descends a valley leading into the Coln,

about a mile and a half south of St. Stephen's. A modern engineer would probably see no reason to alter this road anywhere except at the summit, which he would probably cross between Brockley-hill and Elstree, in a north-westerly direction, taking on each side the hollows of the two streams, which flow on opposite sides and in opposite directions. On the south side of this crossing he would carry the road in a straight line nearly in the valley of the stream, to join the present road somewhere about Edgeware, and on the north side would pass close to the reservoir, and fall into the present road half a mile north of Medburn.

THE GREAT HOLYHEAD ROAD THROUGH BARNET.

THIS was one of the most celebrated of all the roads out of London, as it carried nearly all the traffic between the metropolis and Liverpool, Manchester and Birmingham, besides being the great highway to Ireland, by way of Chester and Holyhead. It is still under the management and direction of a parliamentary board, termed the Commissioners of the London and Holyhead road; with a competent staff of officers and assistants, including an engineer, who reports annually on the state of the whole road.

Like all other turnpike roads, it is, nevertheless, divided into trusts; and the trustees of each district appoint their own surveyor, and exercise a local management of the repairs, &c.; but when any improvements are to be made, these are executed under the control of the parliamentary commissioners and their engineer.

This road, the most important probably in the kingdom for purposes of mail-coach travelling, may be said to commence at the General Post Office in St. Martin's-le-Grand, whence it passes by Goswell-street to the Angel at Islington, and thence through Islington to Holloway. The road formerly ascended up Highgate-hill to the village of Highgate, and descended on the other side to Abbot's-farm; but of late years a great improvement has been made by carrying the road on the east side of Highgate, and making a deep cutting through the hill. This has had the effect both of straightening the road and greatly improving its levels. After leaving Highgate, the road proceeds by Abbot's-farm and Brown's-wells, crossing near their source two small

feeders of the Brent, and then begins to ascend an elevated ridge of country from which tributaries of the Brent rise on one side, and those of the Lea on the other. The road continues about a mile on this ridge, and then passes through Whetstone. It then very gradually descends, passing by Greenhill-grove and the old Poor-house, a little beyond the tenth mile from London. The ascent from the fairfield up to Chipping Barnet was formerly very steep, but of late years has been much improved by a very high embankment, which fills up the hollow, and reduces the inclination to about one in thirty. Passing through the street of Barnet for rather more than a quarter of a mile, the road bends suddenly to the left in the direction of St. Alban's, while the great north road goes straight through the town in the direction of Hatfield. After leaving Barnet, the Holyhead road proceeds on to the Green Dragon; passing between Durham-park on the west, and Wrotham-park, the seat of Mr. Byng, on the east side. It then goes on by Laurel-lodge to South Mims, where a new piece of road has been made to avoid a bend, and then proceeds in a straight line to Ridge-hill, where also the old course of the road has been diverted, and a deep cutting made through the hill. From Ridge-hill the road proceeds to London Colney, where it crosses the river Coln, and thence continues through a tolerably flat country to the Mile-house, situate one mile from St. Alban's. From this place it ascends to and enters St. Alban's on the east side of the town. From St. Alban's the road proceeds in a northern direction through Harpenden, Luton, and Barton, to Bedford; but this road was never much used by coaches going northward from the metropolis, as they used the road which leaves the present one at Barnet, and which will be described next in order. By far the most important road from St. Alban's is the great Holyhead road, which passes on through Dunstable, Hockliffe, Fenny Stratford, Stoney Stratford, Towcester, Weedon, Daventry, Dunchurch, and Coventry, to Birmingham. From Birmingham the great Holyhead road goes on by Wolverhampton and Market Drayton to Chester, and thence by Conway and Bangor, across the Menai-bridge, and through the Isle of Anglesea, to Holyhead.

A considerable section of the modern Holyhead road, namely, from St. Alban's to Weedon Beck, occupies the site of the ancient Roman Watling-street, which went on

between Clifton and Crick to Wibtoft, near Lutterworth, where it intersected the great Fosseway, another Roman road, leading from Cirencester to Lincoln and York. It then went on in a straight line to Atherstone, and thence by Ensor and Fazeley, by Drayton Manor, near Tamworth. Then it went on by Norton and Stretton to Weston and Wellington, and so to Shrewsbury. The first part of the Watling-street from London to St. Alban's has been already described; and as the Holyhead road first adopts the old Roman road at St. Alban's, the question naturally arises, why was the first section of it from the metropolis to St. Alban's rejected in favour of the road by Barnet? The levels of the Roman road are decidedly superior, the distance from the Post Office to St. Alban's about the same by each road, while from the west end of London the Roman is two miles shorter, being only nineteen miles, while the other is twenty-one miles. The principal objections to the Barnet road are the ascent of the Highgate-archway road,—which is still serious, notwithstanding the improvements that have been made,—and the very steep hill on the south side of Barnet. No convenience connected with the peculiar department of the Post Office, such as the delivery of mail-bags at the intermediate villages, could have compelled the use of the Barnet road by the Holyhead, Chester, and Liverpool mails, because the great northern road, which of necessity passes through Barnet, was sufficient to serve for their supply, while the villages between Barnet and St. Alban's are very insignificant, and could have been supplied by foot-posts without any inconvenience. It still remains, therefore, a matter of considerable surprise, why the Barnet road was preferred to the Roman road by Edgeware, not only by the mails, but by nearly all the coaches which made use of the Holyhead road.

THE GREAT NORTH ROAD BY BARNET AND HATFIELD.

This road, as before explained, is identical with the Holyhead road as far as Barnet. It goes on through the long street of that place, and passes by Monken Hadley, skirting for a mile and a half on the east side of Wrotham-park, passing thence by Garwick-corner to Potter's-bar; then on to Littleheath and Swanley-bar, on the east side of Brockman-park, by Bell-bar and Woodside, whence it goes on for a mile through Hatfield-park, the seat of the Mar-

quis of Salisbury; then bends to the north, and skirts the park on the west side as far as the town of Hatfield, through the street of which the descent is very rapid, very crooked, and dangerous. Beyond Hatfield the road goes on by Welwyn and Hitchin to Shefford, Bedford, Higham Ferrers, Kettering, Market Harborough, and Leicester. Another branch, being in fact the great north road, goes off at Welwyn through Baldock, St. Neot's, Alconbury-hill, Stilton, Stamford, Grantham, Newark, East Retford, Bawtry, Doncaster to York, Leeds, Newcastle, Carlisle, Edinburgh, and Glasgow, and all parts of Scotland. The principal objection to this road near London, is the dangerous and inconvenient hill in the town of Hatfield. It is singular that this has been allowed to exist so many years, when the slightest observation of the natural drainage of the country would at once point out how it might be avoided. For a mile and a half before approaching Hatfield, the valley in which the road ought to pass, here distant about half a mile to the west, is distinctly visible. As the Great Northern railway is to pass down this valley for some miles, altogether on the west side of Hatfield-park, an arrangement has been made, and an Act of Parliament obtained, for carrying the road alongside the railway for several miles, by means of which the highly objectionable hill in the town of Hatfield will be entirely avoided, and the new piece of road will join the present one at the lower and northern end of the town, where the ground is quite flat. Many other objections might be taken, not only to the rest of the road between Hatfield and St. Alban's, but to the whole of the road to London. It appears, in fact, that the whole of the first fourteen miles, namely, from London to Potter's-bar, would be improved by adopting the road now used by some of the Hatfield coaches, by Ball's pond, east of Hornsey, Southgate, between Beech hill and Trent-park, and joining the present road at Potter's-bar. This road is not longer than the present turnpike road, which it entirely avoids. Highgate-hill, and the summit corresponding with Barnet-hill, is crossed under much more advantageous circumstances.

RUDIMENTS

OF THE

ART OF CONSTRUCTING ROADS.

CHAPTER I.

THE EXPLORATION OF ROADS.

No surer indication can be afforded of the extent of a country's trade, or even of its advancement in civilisation, than the existence of good and sufficient means of internal communication: for since it is one of the wise dispensations of Providence that many of those commodities which the present artificial state of society teaches us to regard as necessaries, are very unequally distributed, some being wanting in certain localities where again others are only found, it becomes necessary, in order that all may be equally well served, that an interchange of these commodities should take place, so that the whole country may participate equally in the enjoyment and use of those things which would otherwise be confined to only certain districts. Thus, we may have in one part of a country huge forests, stocked with various kinds of timber; in another, extensive tracts of fertile land, capable, if properly cultivated, of yielding supplies of corn and other produce, sufficient for the support of a densely-populated country; in a third, mineral treasures, coal and iron, or the more precious metals; in another, stone, well adapted for the construction of houses, and for other building purposes: and yet, with all these latent treasures dispersed throughout the country, of what avail would they be, unless the means were possessed of conveying them to every part of the land, and

thus distributing to all what would otherwise be enjoyed but by a few?

It is not, however, only for the purposes of its own internal trade that good means of communication are required; they become even more necessary, to ensure an extensive commerce with foreign countries, to enable the peculiar produce of the several districts to be brought together to those parts of the coast which have been either naturally or artificially formed into ports, and then again to distribute to every part of the country the goods brought in exchange from foreign lands, comprising frequently the necessaries as well as the luxuries of human life.

And further, good means of internal communication are essential for the proper defence of a country (whether island or continental) against either the attacks of foreign aggressors or civil tumults, rendering a much smaller standing army necessary for this purpose than would otherwise be required, and reducing one of the most costly and most odious burdens which a civilised country can be subjected to.

Such being the case, it will not be a matter of surprise that, from the earliest periods, and in all nations having any pretensions to civilisation, the establishment and improvement of the means of internal communication has always been regarded as a consideration of primary importance; and one which has engaged the highest talents of the civil engineer, the result of whose exertions devoted to this object has been the perfection of common roads, railways, and canals.

It is not necessary to enter into the comparative merits or advantages of these several means of communication, in order to establish the importance and necessity of common roads. For although, under certain circumstances, it might be questionable which of the three would be the best adapted for serving the tract of country through which it was to pass, there are an innumerable number of cases in which only the common road could be advantageously employed. Railways and navigable rivers or canals may be

regarded as the arteries of traffic; while common roads are simply the veins or smaller ramifications through which the means of conveyance are carried into every nook and corner of the land. It would be quite impracticable so to intersect any country with canals or railways as to obviate the necessity of common roads, or to make the former universally supersede the latter.

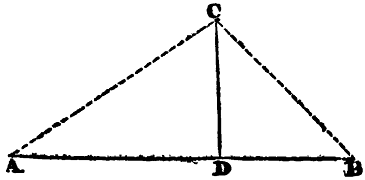
The formation of a perfect general system of railway communication necessitates the construction of several new common roads, in order that towns situated at some distance from the nearest line of railway may fully participate in the benefits to be derived from it.

We have been led into these remarks because many might think that, since the general adoption of railways, the construction of common roads had become of minor importance, and was hardly worthy of much consideration; whereas, in truth, they are in a great degree mutually dependent upon each other, as regards their utility and success. The present work is confined entirely to the art of constructing common roads, in situations where none previously existed, and to the repair of those already made.

Before entering into the practical details of their construction, it will be desirable to go into the subject of the *exploration* of roads, or the manner in which a person should proceed in exploring a tract of country for the purpose of determining the best course for a road, and the principles which should guide him in his final selection of the same.

Let us suppose that it is desired to form a road between two distant towns, A and B, fig. 1, and let us, for the present, neglect altogether the consideration of the physical

FIG. 1.



features of the intervening country; assuming that it is equally favourable, whatever line we select. Now, at first sight, it would appear that, under such circumstances, a perfectly straight line drawn from one town to the other would be the best that could be chosen. On a more careful examination, however, of the locality, we may find that there is a third town, C, situated somewhat on one side of the straight line which we have drawn from A to B; and, although our primary object is to connect only the two latter, that it would, nevertheless, be of considerable service if the whole of the three towns were put into mutual connection with each other. Now this may be effected in three different ways; any one of which might, under certain circumstances, be the best. In the first place, we might, as originally suggested, form a straight road from A to B, and, in a similar manner, two other straight roads from A to C, and from B to C, and this would be the most perfect way of effecting the object in view; the distance between any two of the towns being reduced to the least possible. It would, however, be attended with considerable expense, and it would be requisite to construct a much greater length of road than according to the second plan, which would be to form, as before, a straight road from A to B, and from C to construct a road which should join the former at a point D, so as to be perpendicular to it; the traffic between A or B and C, would proceed to the point D, and then turn off to C: with this arrangement, while the length of the roads would be very materially decreased, only a slight increase would be occasioned in the distance between C and the other two towns. The third method would be to form only the two roads A C and C B, in which case the distance between A and B would be somewhat increased, while that between A and C, or B and C, would be diminished; the total length of road to be constructed would also be lessened.

As a general rule it may be taken, that the last of these methods is the best, and most convenient for the public; that is to say, that if the physical character of the country

does not determine the course of the road, it will generally be found best not to adopt a perfectly straight line, but to vary the line so as to pass through all the principal towns near its general course; for the reason, that the public may be conveyed from town to town with greater facility and less expense than if the straight line were adopted, and the towns were merely made to communicate with it by means of branch roads: since, with the first arrangement, any vehicles established to convey passengers or goods between the two terminal towns, would pass through all those which were intermediate; while, if the straight line and branch-road system were adopted, it would be requisite also to have a system of branch coaches to meet the coaches on the main line.

In laying out a road in an old country which has been long inhabited, and in which the position of the various towns, &c., requiring road accommodation is therefore already determined, we are left less at liberty in the choice and selection of the line of road, and must be guided in that choice by different considerations to those which would determine the line of a road made through a new country, where our only object was to establish the easiest and best road between two distant stations. In the first case we should take into consideration the position of the various towns and other inhabited districts situated near the intended road, and its course would be, to a certain extent, controlled thereby; while, in the second case, we should simply examine the physical characters of the country, and base all our proceedings on the result.

Whichever of these two cases, however, may have to be dealt with, in the ultimate selection and adoption of the line of road between those points which are fixed by other circumstances, the same careful examination of the physical character of the country should be made, and the same principles should control the choice.

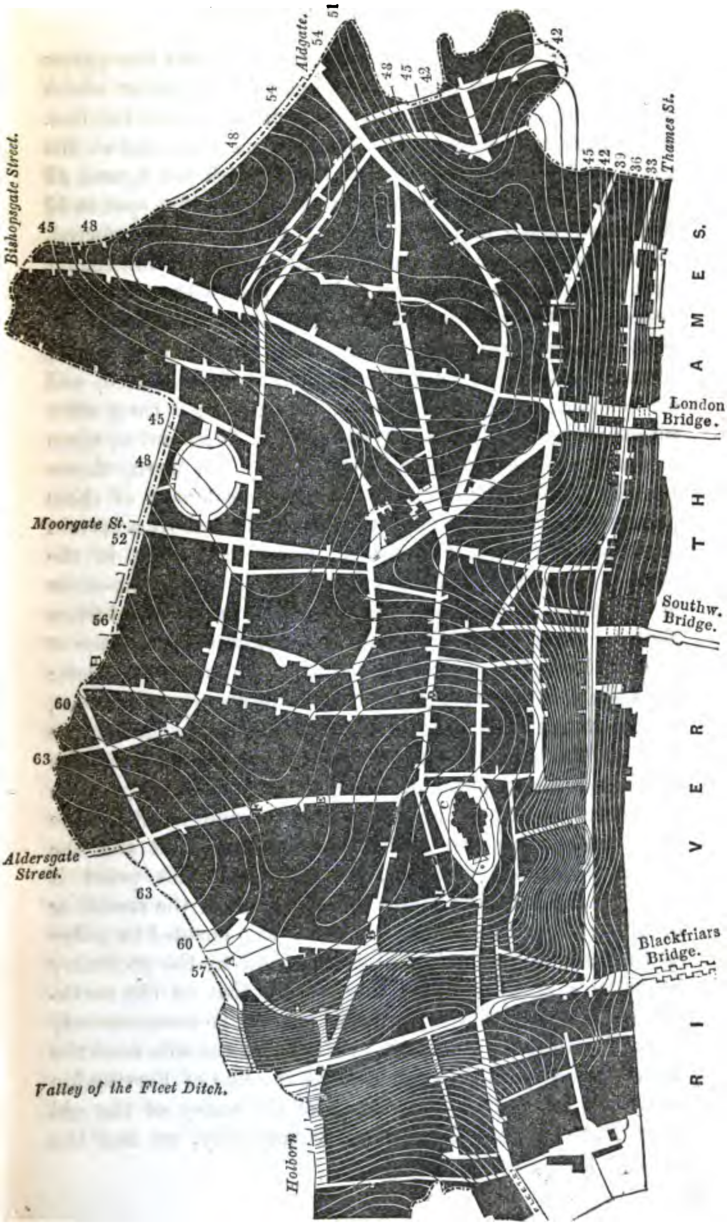
In examining almost any tract of country, one of the first points which must attract our notice is the unevenness or undulations of its surface; but if we extend our observation

a little further, we shall perceive, even in the most apparently irregular countries, the same general principle of conformation. We shall find the country intersected in various directions by rivers decreasing in size as they leave their point of discharge; from these main rivers we shall find lesser ones branching off on both sides, and running right and left through the country, and from these again still smaller streams and brooks; furthermore, we shall find the ground falling in every direction towards these natural watercourses, forming a ridge, more or less elevated, running between them, and separating from each other the districts drained by each separate stream.

In all cases it should be the first business of a person, engaged in laying down a line of road, to make himself thoroughly acquainted with all these features of the country; he should possess himself of a plan or map, showing accurately the course of all the rivers and principal watercourses, and upon this he should further mark the lines of greatest elevation, or the ridges separating the several valleys through which they flow; it would also be of peculiar service if the plan contained contour lines showing the comparative levels of any two points, and the rates of declivity of every portion of the country's surface. The system of showing upon plans the levels of the ground by means of *contour lines* is one of so much utility, not only in the selection of roads and all other lines of communication, but in the drainage of towns, as well as their supply with water, in the drainage and irrigation of lands, and for almost all purposes, that we have inserted a plan of the City of London* (fig. 2), which illustrates its application. It will be observed that, upon this plan, there are a number of fine lines traversing its surface in various directions, and, where they approach the borders of the map, having figures written against them: these lines are termed *contour lines*, and they denote that the level of the ground is identical throughout the whole of their course, that

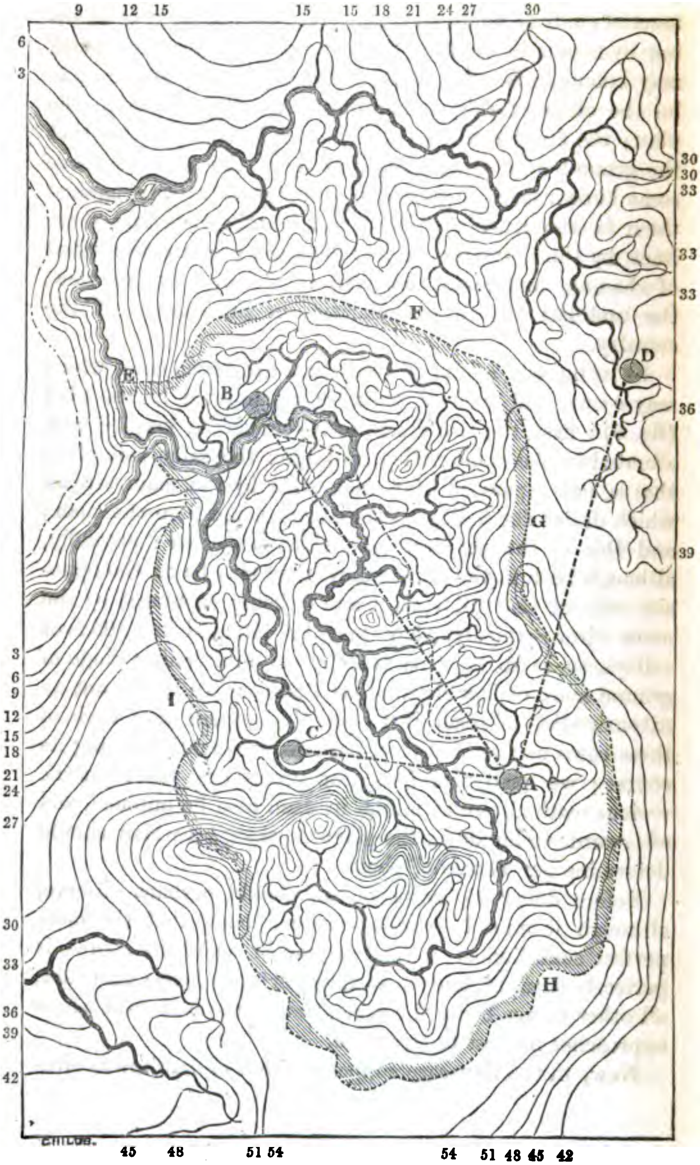
* This plan is taken from the Report on the Health of Towns, and is made from levels taken from Mr. Butler Williams.

FIG. 2.



Bishopsgate Street.
Aldgate.
Thames St.
THAMES.
London Bridge.
Moorgate St.
Southw. Bridge.
Aldersgate Street.
RIVER
Blackfriars Bridge.
Valley of the Fleet Ditch.
Holborn

Fig. 3.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ated on the same side of the main valley), there are two methods which might be pursued in forming a communication between them: we might either make a road following the direct line between them, shown by the thick dotted line A B, or we might adopt a line which should gradually and equally incline from one town to the other, supposing them to be at a different level, or, if at the same, keeping at that level throughout its entire course, and following all the sinuosities and curves which the irregular formation of the country might render necessary for the fulfilment of these conditions. And in the first method (that of a direct line between the two places), we might either form a level or equally-inclined road from one to the other, forming embankments and cuttings where necessary to attain these objects, or we might avoid these expensive works, and make the surface of the road conform to that of the country. Now, of all these the best is the straight and equally-inclined (or level, as the case may be) road, although at the same time it is the most expensive; and if the importance of the traffic passing between the places is not sufficient to warrant so great an outlay, it will then become a matter of consideration whether the course of the road should be kept straight, its surface being made to undulate with the natural face of the country, or whether, a level or equally-inclined line being taken for its surface, the course of the road should be made to deviate from the direct line, and follow the winding course which such a condition is supposed to necessitate.

In the second case, that of two places situated on opposite sides of the same valley, we have, in like manner, the choice of a perfectly straight line to connect them, which would probably require a heavy embankment if the road were kept level, or steep inclines if it followed the surface of the country; or we may, by winding the road, carry it across the valley at a higher point, where, if the level road were taken, the embankment would not be so high, or, if kept on the surface, the inclination would be reduced.

In the third case, we have in like manner the alternative

of carrying the road across the intervening ridge in a perfectly straight line, or of deviating to the right or left, and crossing at a point where the ridge is less elevated.

In all these cases, the proper determination of the question, which of these courses is the best under certain circumstances, involves one of the most difficult points to solve, which is, the comparative advantages and disadvantages of inclines and curves; that is, what additional increase in the length of a road would be equivalent to a given inclined plane upon it, or conversely, what inclination might be given to a road, as an equivalent to a given decrease in its length. In order to a correct solution of these questions, it is requisite that we should know the comparative force required to draw different vehicles with given loads upon level and variously-inclined roads. We shall, therefore, before proceeding further, investigate this subject, and show the manner in which we may determine the tractive force required upon roads of any given inclination.

It has been attempted to investigate mathematically the resistances which oppose themselves to the motion of various descriptions of vehicles drawn along horizontal roads, whose surfaces were formed of different materials, and in different states of smoothness. No satisfactory result, however, has been obtained, because we are ignorant of the data which are essentially requisite to enable us to arrive at a correct conclusion. We should, for instance, know the relative amounts of resistance occasioned by a wheel drawn along a hard smooth road, such as a good macadamized road, so hard that the wheel can make no appreciable impression upon it; upon the same road when newly covered with stones, and when the passing of the wheel over them crushes these stones in a greater or less degree; upon a gravel road, the surface of which is soft, so that the wheel in its passage sinks into the road and forms a rut; upon a similar road covered with stones which are partially crushed and partially forced down into the soft road by the wheel passing over them; or upon a stone pave-

ment, such as is common in the streets of towns, laid with more or less regularity, and in passing over which the resistance is felt in jerks, as the wheels bound from stone to stone. Many other cases might be mentioned, in which we should be equally at a loss to assign a correct value to the resistance which would be experienced by a carriage drawn along the particular description of road supposed. Although, therefore, some of the attempts which have thus been made have been very ingenious, and have shown the mathematical skill of the investigator, they have done little besides, and would be out of place in the present work. In cases of this description, the best practical method of proceeding is by experiments sufficiently careful and extensive to determine the amount of resistance in each particular case, from which we may then determine an empyrical formula or rule, which will enable us to generalise the results of our experiments, and apply them with sufficient accuracy for practical purposes to any particular case we may wish.

The following are the general results of the experiments made by M. Morin upon this subject, at the expense of the French Government:—

1st. The traction is directly proportional to the load, and inversely proportional to the diameter of the wheel.

2nd. Upon a paved or hard macadamized road the resistance is independent of the width of the tire, when it exceeds from three to four inches.

3rd. At a walking pace the traction is the same, under the same circumstances, for carriages with springs and without them.

4th. Upon hard macadamized, and upon paved roads, the traction increases with the velocity: the increments of traction being directly proportional to the increments of velocity above the velocity 3·28 feet per second, or about 2¼ miles per hour. The equal increment of traction thus due to each equal increment of velocity is less as the road is more smooth, and the carriage less rigid or better hung.

5th. Upon soft roads of earth, or sand or turf, or roads

fresh and thickly gravelled, the traction is independent of the velocity.

6th. Upon a well-made and compact pavement of hewn stones, the traction at a walking pace is not more than three-fourths of that upon the best macadamized roads under similar circumstances; at a trotting pace it is equal to it.

7th. The destruction of the road is in all cases greater, as the diameters of the wheels are less, and it is greater in carriages without than with springs.

The next experiments which we shall quote, are those of Sir John Macneill,* made with an instrument invented by him for the purpose of measuring the tractive force required on different descriptions of road, under various circumstances. The general results which he obtained are given in the following table, the numbers in which exhibit the tractive force requisite to move a weight of a ton under ordinary circumstance, at a very low velocity upon the several kinds of road mentioned.

Description of road.	Force, in pounds, required to move a ton.
On a well-made pavement	33
On a road made with six inches of broken stone of great hardness, laid either on a foundation of large stones, set in the form of a pavement, or upon a bottoming of concrete	46
On an old flint road, or a road made with a thick coating of broken stone, laid on earth	65
On a road made with a thick coating of gravel, laid on earth	147

Sir John Macneill has also given the following arbitrary formulæ,† for calculating the resistance to traction on various kinds of roads; they have been deduced from a considerable number of experiments made on the different kinds of road specified below, with carriages moving at various velocities. Putting R for the force required to

* Sir H. Parnell on Roads, p. 73. † Ibid., p. 464.

move the carriage, W the weight of the carriage, w that of the load, all expressed in pounds, v the velocity in feet per second, and c a constant number, which depends upon the surface over which the carriage is drawn, and the value of which for several different kinds of road is as follows:—

On a timber surface	c =	2
On a paved road	"	2
On a well-made broken stone road, in a dry clean state	"	5
On a well-made broken stone road, covered with dust	"	8
On a well-made broken stone road, wet and muddy	"	10
On a gravel or flint road, in a dry clean state	"	13
On a gravel or flint road, in a wet and muddy state	"	32

We have, in the case of a common stage wagon—

$$R = \frac{W + w}{93} + \frac{w}{40} + c\,v; \quad . \quad . \quad . \quad . \quad . \quad . \quad (1.)$$

and in the case of a stage coach—

$$R = \frac{W + w}{100} + \frac{w}{40} + c\,v; \quad . \quad . \quad . \quad . \quad . \quad . \quad (2.)$$

These formulæ, being reduced to verbal rules for the convenience of those not conversant with algebraical expressions, are as follows:—

RULE.—Divide the weight of the carriage when loaded, in pounds, by 93 if a wagon, or 100 if a coach, and to the quotient add one-fortieth of the weight of the load only; the sum, added to the velocity in feet per second, multiplied by the proper number taken from the above table for the particular kind of road, will give the force in pounds required to draw the carriage at the given velocity upon that description of road.

For example: what force would be requisite to move a stage-coach weighing 2,060 lbs., and having a load of 1,100 lbs., at a velocity of 9 feet per second, along a broken stone road covered with dust?

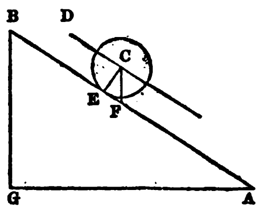
Here we have

$$\frac{2060 + 1100}{100} + \frac{1100}{40} + 8 \times 9 = 131{\cdot}1 \text{ lbs.}$$

for the force required.

We next pass on to consider the additional resistance which is occasioned when the road, instead of being level, is inclined in a greater or less degree. In order to simplify the question, let us suppose the whole weight to be supported on one pair of wheels, and that the tractive force is applied in a direction parallel to the surface of the road. On this supposition let A B (fig. 4) represent a portion of an inclined road, C being a carriage just sustained in its

FIG. 4.



position by a force acting in the direction C D; now it is evident that the carriage is kept in its position by three forces, namely, by its own weight (equal W) acting in the vertical direction C F, by the force (equal F) applied in the direction C D parallel to the surface of the road, and by the pressure (equal P) which the carriage exerts against the surface of the road acting in the direction C E, perpendicular to the same. To determine the relative magnitude of these three forces, draw the horizontal line A G, and the vertical one B G; then, since the two lines C F and B G are parallel, and are both cut by the line A B, they must make the two angles C F B and A B G equal; also the two angles C E F and A G B are equal, being both right angles; therefore the remaining angles F C E and B A G are equal, and the two triangles C F E and A B G are similar. And as the three sides of the former are proportional to the three forces by which the carriage is sustained, so also are the three sides

of the latter, namely, A B, or the length of the road is proportional to W, or the weight of the carriage, B G, or the vertical rise in the same to F, or the force required to sustain the carriage on the incline, and A G on the horizontal distance in which this rise occurs to P, or the force with which the carriage presses upon the surface of the road.

We have, therefore,

$$W : AB :: F : GB,$$
$$\text{and } W : AB :: P : AG.$$

And if we make A G such a length that the vertical rise of the road is exactly one foot, we shall have

$$F = \frac{W}{AB} = \frac{W}{\sqrt{AG^2 + 1}} = W . \sin \beta \quad . \quad . \quad (3.)$$

$$\text{and } P = \frac{W . AG}{AB} = \frac{W . AG}{\sqrt{AG^2 + 1}} = W . \cos \beta \quad . \quad . \quad (4.)$$

in which β is the angle B A G.

These formulæ reduced to verbal rules are as follows:—

To find the force requisite to sustain a carriage upon an inclined road (the effects of friction being neglected), divide the weight of the carriage, including its load, by the *inclined* length of the road, the vertical rise of which is one foot, and the quotient is the force required.

To find the pressure of a carriage against the surface of an inclined road, multiply the weight of the loaded carriage by the *horizontal* length of the road, and divide the product by the *inclined* length of the same; the quotient is the pressure required.

Example.—What is the force required to sustain a carriage weighing 3,270 lbs. upon a road, the inclination of which is one in thirty, and what is the pressure of the same upon the surface of the road?

Here the horizontal length of the road (A G) being 30, the inclined length ($AB = \sqrt{AG^2 + 1}$) is 30·017, and we have, by the first rule, 3,270 ÷ 30·017 = 108·93 lbs. for the force required to sustain the carriage on the road; and,

by the second rule, $(3{,}270 \times 30) \div 30{\cdot}017 = 3{,}269{\cdot}9$ lbs. for the pressure of the carriage upon the surface of the road.

Since the pressure of a carriage on a sloping road is found by multiplying its weight by the horizontal length of the road and dividing by the inclined length, and as the former is always less than the latter, it follows that the force with which a carriage bears upon an inclined road is less than its actual weight, as will be seen in the foregoing example, in which it is about two pounds less; unless, however, the inclination is very steep, it is not necessary to calculate the pressure, which may be assumed to be equal to the weight of the carriage.

If R expresses the resistance which has to be overcome in moving any particular carriage at a given rate upon a horizontal road, then R × F will be the resistance upon ascending a hill, and R − F upon descending a hill, with the same velocity, in both cases neglecting the decrease in the weight of the carriage produced by the inclination of the road. Taking, however, this decrease into consideration, the following modification in the formulæ (1.) and (2.) will be requisite to adapt them to an inclined road:—

$$\text{R} = \left(\frac{\text{W} + w}{93} + \frac{w}{40}\right) . \cos\beta \mp (\text{W} + w) . \sin + \beta + c\,v . \text{(5.)}$$

in the case of a common stage wagon, and in that of a stage coach,

$$\text{R} = \left(\frac{\text{W} + w}{100} + \frac{w}{40}\right) . \cos\beta \mp (\text{W} + w) . \sin\beta + c\,v . \text{(6.)},$$

the upper sign being taken when the vehicle is drawn down the incline, and the lower when it is drawn up the same.

Neglecting the decrease in the weight of the carriage, in order to ascertain the resistance in passing up or down a hill, we have only to calculate by the rule already given at page 64 the resistance on a level road, to which, if the carriage ascends the hill, we must add, or if it descends, subtract, the force requisite to sustain the carriage on the

inclined road, calculated by the rule at page 66; the sum or difference, as the case may be, will express the resistance required.

As an example, let us take, as before, the case of a stage-coach weighing 2,060 lbs., besides a load of 1,100 lbs., and having to be moved at a velocity of 9 feet per second, along a broken stone road whose surface is covered with dust, and inclined at the rate of one in thirty.

Then the force to sustain the coach on this slope will be

$$\frac{3160}{30} = 105{\cdot}3 \text{ lbs.}$$

which, added to the force already found at page 60 as being requisite to move the same coach on a level road, will be $(105{\cdot}3 + 131{\cdot}1 =)$ $236{\cdot}4$ lbs. for the force required to move the coach with a velocity of 9 feet per second *up* an inclination of one in thirty; and subtracted from the same, will be $(131{\cdot}1 - 105{\cdot}3 =)$ $25{\cdot}8$ lbs., the force required to move the coach with the same velocity *down* the same inclination.

The same example worked by formula (6) will give

$$\left(\frac{2060 + 1100}{100}\right) \cdot 9995 + (2060 + 1100) \cdot 0333 + 8 \times 9$$

$$= 236{\cdot}3 \text{ lbs.}$$

when the carriage is drawn up the incline, and

$$\left(\frac{2060 + 1100}{100}\right) \cdot 9995 - (2060 + 1100) \cdot 0333 + 8 \times 9$$

$$= 25{\cdot}84 \text{ lbs.}$$

when the carriage is drawn down the incline, the result being the same as that given by the rule.

The following table has been calculated in order to show with sufficient exactness for most practical purposes the force required to draw carriages over inclined roads, and the comparative advantage of such roads and those which are perfectly level. The first column expresses the rate of inclination, and the second the equivalent angle; the

two next columns contain the force requisite to draw a common stage-wagon weighing with its load 6 tons, at a velocity of 4·4 feet per second (or 3 miles per hour) along a macadamized road in its usual state, both when the hill ascends and when it descends; the fifth and sixth columns contain the length of level road which would be equivalent to a mile in length of the inclined road, that is, the length which would require the same mechanical force to be expended in drawing the wagon over it as would be necessary to draw it over a mile of the inclined road; the four next columns contain the same information as the four last described, only with reference to a stage coach supposed to weigh with its load 3 tons, and to travel at the rate of 8·8 feet per second, or 6 miles per hour.

Rate of Inclination.	Angle with the Horizon.			For a Stage Wagon.				For a Stage Coach.			
				Force required to draw the wagon *up* the incline.	Force required to draw the wagon *down* the incline.	Equivalent length of level road for an *ascending* wagon.	Equivalent length of level road for a *descending* wagon.	Force required to draw the coach *up* the incline.	Force required to draw the coach *down* the incline.	Equivalent length of level road for an *ascending* coach.	Equivalent length of level road for a *descending* coach.
	°	′	″	lbs.	lbs.	Miles.	Miles.	lbs.	lbs.	Miles.	Miles.
1 in 600	0	5	44	286	241	1·085	·9150	373	350	1·030	·9690
„ 575	0	5	59	287	240	1·088	·9116	373	350	1·032	·9676
„ 550	0	6	15	288	239	1·093	·9074	374	349	1·033	·9662
„ 525	0	6	33	289	238	1·097	·9029	374	349	1·035	·9646
„ 500	0	6	53	291	237	1·102	·8979	375	348	1·037	·9629
„ 475	0	7	14	292	235	1·107	·8926	376	347	1·039	·9605
„ 450	0	7	38	294	234	1·113	·8869	377	347	1·041	·9588
„ 425	0	8	5	295	232	1·120	·8801	377	346	1·043	·9563
„ 400	0	8	36	297	230	1·128	·8725	378	345	1·046	·9535
„ 375	0	9	10	300	228	1·136	·8642	380	344	1·049	·9505
„ 350	0	9	49	302	225	1·146	·8543	381	342	1·053	·9469
„ 325	0	10	35	305	222	1·157	·8433	382	341	1·056	·9430
„ 300	0	11	28	309	219	1·170	·8301	384	339	1·061	·9381
„ 290	0	11	51	310	217	1·176	·8245	385	338	1·064	·9358
„ 280	0	12	17	312	216	1·182	·8179	386	338	1·066	.9336
„ 270	0	12	44	314	214	1·189	·8111	386	337	1·068	·9314
„ 260	0	13	13	315	212	1·196	·8039	387	336	1·071	·9286
„ 250	0	13	45	317	210	1·204	·7963	388	335	1·074	·9259
„ 240	0	14	19	320	208	1·212	·7876	390	334	1·077	·9226
„ 230	0	14	57	322	205	1·222	·7785	391	332	1·080	·9192
„ 220	0	15	37	325	203	1·232	·7683	392	331	1·084	·9156
„ 210	0	16	22	328	200	1·243	·7573	394	330	1·088	·9115
„ 200	0	17	11	331	197	1·255	·7451	395	328	1·092	·9071
„ 190	0	18	6	334	193	1·268	·7319	397	326	1·097	·9024
„ 180	0	19	6	338	189	1·283	·7171	399	324	1·103	·8968
„ 170	0	20	13	343	185	1·300	·7004	401	322	1·109	·8908
„ 160	0	21	29	348	180	1·319	·6814	404	320	1·116	·8839
„ 150	0	22	55	353	174	1·341	·6587	406	317	1·123	·8761
„ 140	0	24	33	360	168	1·364	·6359	410	314	1·132	·8673
„ 130	0	26	27	367	160	1·392	·6079	413	310	1·142	·8573
„ 120	0	28	39	376	152	1·425	·5752	418	306	1·154	·8451
„ 110	0	31	15	386	142	1·451	·5491	423	300	1·169	·8308
„ 100	0	34	23	398	129	1·510	·4903	429	294	1·185	·8142
„ 95	0	86	11	405	122	1·537	·4634	432	291	1·195	·8045
„ 90	0	38	12	413	114	1·566	·4338	436	287	1·206	·7937
„ 85	0	40	27	422	106	1·600	·4004	441	282	1·219	·7801
„ 80	0	42	58	432	96	1·637	·3629	446	278	1·232	·7677

Rate of Inclination.	Angle with the Horizon.			For a Stage Wagon.				For a Stage Coach.			
				Force required to draw the wagon *up* the incline.	Force required to draw the wagon *down* the incline.	Equivalent length of level road for an *ascending* wagon.	Equivalent length of level road for a *descending* wagon.	Force required to draw the coach *up* the incline.	Force required to draw the coach *down* the incline.	Equivalent length of level road for an *ascending* coach.	Equivalent length of level road for a *descending* coach.
	°	′	″	lbs.	lbs.	Miles.	Miles.	lbs.	lbs.	Miles.	Miles.
1 in 75	0	45	51	443	85	1·680	·3204	451	272	1·247	·7522
„ 70	0	49	7	456	72	1·728	·2719	457	266	1·265	·7345
„ 65	0	52	54	470	57	1·784	·2161	465	258	1·285	·7143
„ 60	0	57	18	488	40	1·850	·1505	474	250	1·309	·6903
„ 55	1	2	30	508	19	1·926	·0736	484	239	1·337	·6620
„ 50	1	8	6	533	—	2·019	—	496	227	1·371	·6283
„ 45	1	16	24	562	—	2·133	—	511	212	1·412	·5871
„ 40	1	25	57	600	—	2·274	—	530	194	1·464	·5354
„ 35	1	38	14	648	—	2·456	—	554	170	1·530	·4690
„ 34	1	41	8	659	—	2·499	—	559	164	1·546	·4535
„ 33	1	44	12	671	—	2·544	—	565	158	1·562	4370
„ 32	1	47	27	684	—	2·593	—	572	152	1·580	·4193
„ 31	1	50	55	697	—	2·644	—	578	145	1·599	·4007
„ 30	1	54	37	712	—	2·699	—	586	138	1·619	·3805
„ 29	1	58	34	727	—	2·758	—	593	130	1·640	·3592
„ 28	2	2	5	744	—	2·820	—	602	122	1·663	·3363
„ 27	2	7	2	762	—	2·888	—	610	113	1·688	·3119
„ 26	2	12	2	781	—	2·960	—	620	103	1·714	·2854
„ 25	2	17	26	801	—	3·038	—	630	93	1·743	·2566
„ 24	2	23	10	823	—	3·120	—	641	82	1·774	·2257
„ 23	2	29	22	847	—	3·213	—	653	69	1·808	·1919
„ 22	2	36	10	874	—	3·313	—	666	56	1·844	·1554
„ 21	2	43	35	903	—	3·423	—	681	42	1.884	·1150
„ 20	2	51	21	933	—	3·538	—	696	26	1·926	·0730
„ 19	3	0	46	970	—	3·677	—	714	8	1·977	·0221
„ 18	3	10	47	1009	—	3·826	—	734	—	2·032	—
„ 17	3	21	59	1053	—	3·991	—	756	—	2·092	—
„ 16	3	34	35	1102	—	4·178	—	780	—	2·160	—
„ 15	3	48	51	1157	—	4·388	—	807	—	2·234	—
„ 14	4	5	14	1221	—	4·629	—	839	—	2·322	—
„ 13	4	23	56	1294	—	4·906	—	875	—	2·423	—
„ 12	4	45	49	1379	—	5·229	—	918	—	2·540	—
„ 11	5	11	40	1480	—	5·611	—	968	—	2·679	—
„ 10	5	42	58	1600	—	6·067	—	1028	—	2·846	—
„ 9	6	20	25	1747	—	6·623	—	1101	—	3·048	—
„ 8	7	7	30	1929	—	7·315	—	1192	—	3·300	—
„ 7	8	7	48	2162	—	8·199	—	1308	—	3·621	—

The foregoing table may be considered as affording a view of the comparative disadvantage of hilly roads with light and heavy traffic; the stage wagon, weighing 6 tons and travelling at the speed of 3 miles per hour, may be taken as a fair average for goods traffic, and the stage coach, weighing 3 tons and running 6 miles an hour, for passenger traffic. From the table we perceive that hills act much more unfavourably on the former than on the latter. The force which would be requisite to move the wagon on a level road would be 264 lbs., and that to move the coach 362 lbs., being an excess of 98 lbs. for the traction of the coach; but with a road inclined at the rate of 1 in 600, this excess is only (373 − 286 =) 87 lbs., and when the inclination of the road amounts to about 1 in 70 the forces required to draw them become equal; as the inclination of the road increases beyond this, the excess of the force requisite to draw the wagon over that necessary to move the coach increases rapidly (as will be seen in the table), until, at an inclination of 1 in 7, it amounts to (2162 − 1308 =) 854 lbs.

If we compare the forces required to draw either the wagon or coach up and down any given incline, we shall find that the former is as much greater than the force required on a level road as the latter is less than the same; it might thence be concluded that in the case of a vehicle passing alternately along the road, no real loss would be occasioned by the inclination of the road, since as much power would be gained in the descent of the hill as was lost in its ascent. Such is not, however, practically the fact, for while the inclinations of the road render it necessary in the ascending journey to have either a greater number or more powerful horses than would be requisite if the road were entirely level, no corresponding reduction can be made in the descending journey; we must still have horses sufficient to draw the vehicle along the level portions of the road; nor will (generally speaking) the horses have less to do in descending the hill, since they have frequently to

push back, to prevent the speed of the coach becoming accelerated beyond the bounds of safety.

In a practical point of view, therefore, we may consider that the fifth and ninth columns in the foregoing table express the length of level road which would be equivalent to a mile of road with the stated inclination, the former giving the result for heavy traffic, and the latter for passenger traffic. For instance, opposite 1 in 75, we find in the ninth column 1·247 miles, or nearly a mile and a quarter, stated as the length of a road having that inclination which would be equivalent to one mile of a similar road perfectly level, because the same force would be requisite to move a coach of 3 tons at a velocity of 6 miles per hour along one as along the other. Although, however, they might be considered equal as far as the power requisite for traction was concerned, in other respects one might be more advantageous than the other; as for instance, the shorter road would cost least for repairing, and would occupy least time in being passed over. The table, therefore, merely expresses the equivalent length as far as the mechanical power required for the traction is concerned; the relative merits in other respects depending generally upon so many various circumstances as to render it quite impossible to lay down any specific rules for their determination.

We shall now return to the subject of the selection of route, and proceed to explain the course which should be pursued to obtain the requisite data, to enable a correct determination to be arrived at.

In laying out a new line of road, the first proceeding is usually, after a general examination of the country, to lay down upon the best map which can be procured one or more lines, for the purpose of being more carefully examined. If possessed of a contour map of the district, such as we have described, this proceeding will be greatly facilitated; we shall, however, suppose that such is not the case, since there are very few instances in which a roadmaker would be likely to find such a plan for his use. His

next proceeding should be, to make an accurate survey of the lands through which the several lines that he has sketched out pass, which should be afterwards plotted, or laid down to such a scale as will allow the smallest features to be shown with sufficient accuracy and distinctness: a scale of ten chains to the inch for the open country, with enlarged plans of towns and villages upon a scale of three chains to the inch, will generally be found sufficient. Careful levels should also be taken along the course of each line; and at certain distances (depending upon the nature of the country) lines of levels should be taken at right angles with the original line. In taking these levels the heights of all existing roads, rivers, streams, or canals, should be noted, and *bench marks* should be left at least every half-mile, that is, marks made on any fixed object, such as a gate-post, or the side of a house or barn, &c., the exact height of which is ascertained, and registered in the level-book, so that, in case of a deviation being made in any portion of the lines, the levels of that part may be taken without the necessity of again going over the other parts of the line. A section should be formed from these levels, having the same horizontal scale as the general plan, and such a vertical scale as will show with distinctness the inequalities of the ground: if the horizontal scale is ten chains to the inch, the vertical scale may be 20 feet to the inch.

Fig. 5 is supposed to be such a plan as we have described, plotted on a scale of ten chains to the inch, and showing a district through which it is wished to form a road; we have shown one line running nearly straight across the plan, and a deviation therefrom, which, although longer, would run on more favourable ground. Figs. 6 and 7 are sections showing the levels of the surface of the ground, the former on the straight line, and the latter on the deviation from it. We have shown in these sections and on the plan the information which will be requisite in enabling the engineer to lay down the course of the road, and to arrange the position and dimensions of the various culverts, bridges, and other works belonging to the same.

Fig. 5.

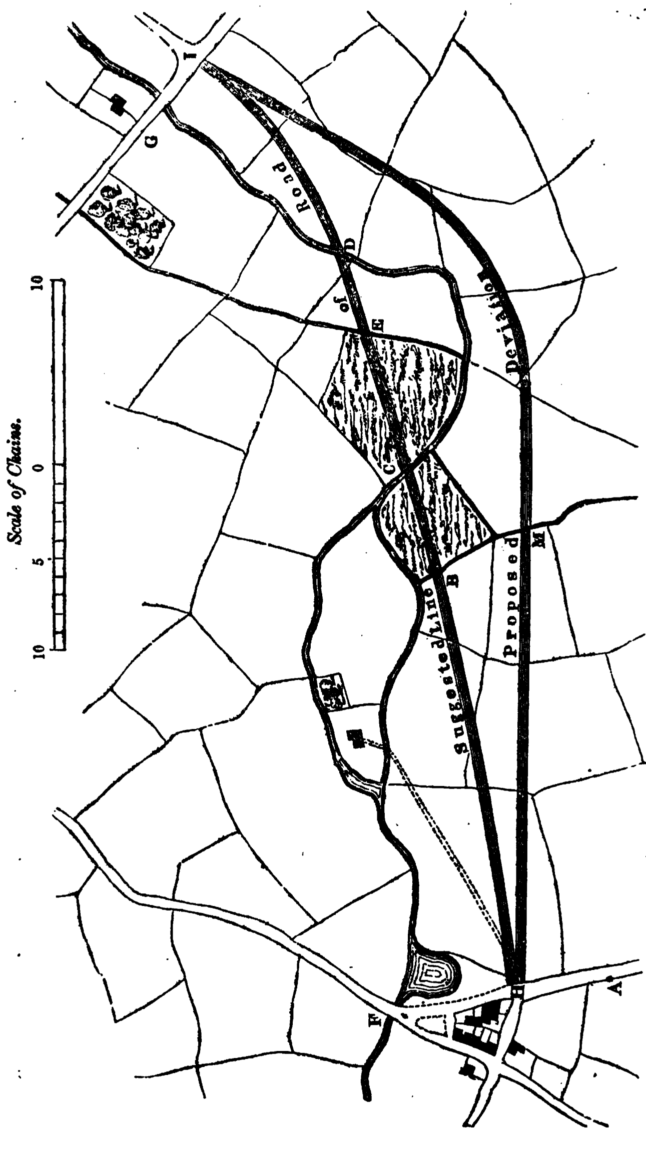

Scale of Chains.
10
5
0
5
10
Road
of
Deviation
Suggested Line
Proposed
A
B
C
D
E
F
G
I
M

FIG. 6.

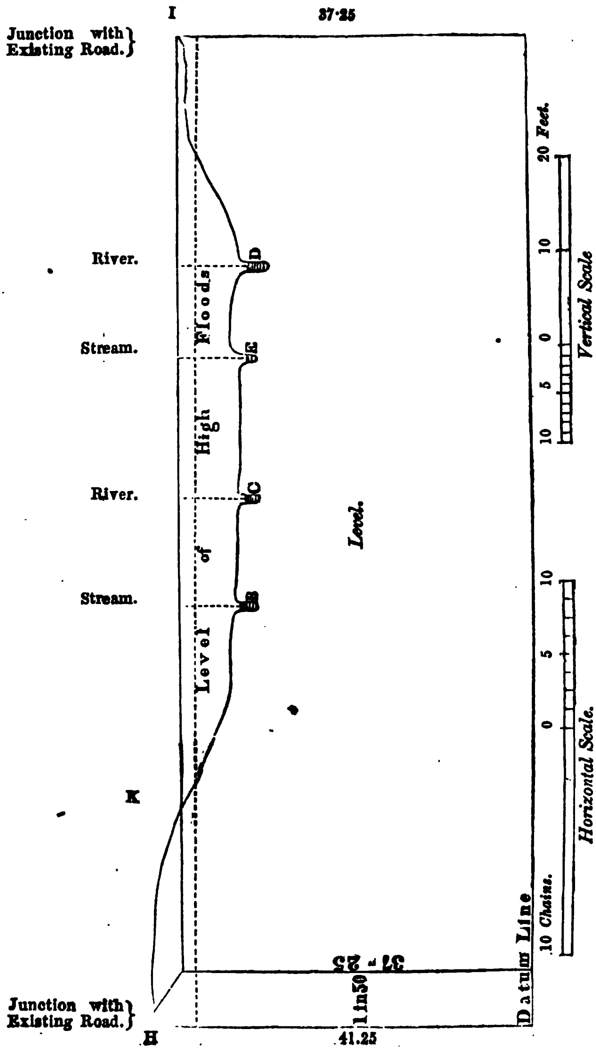
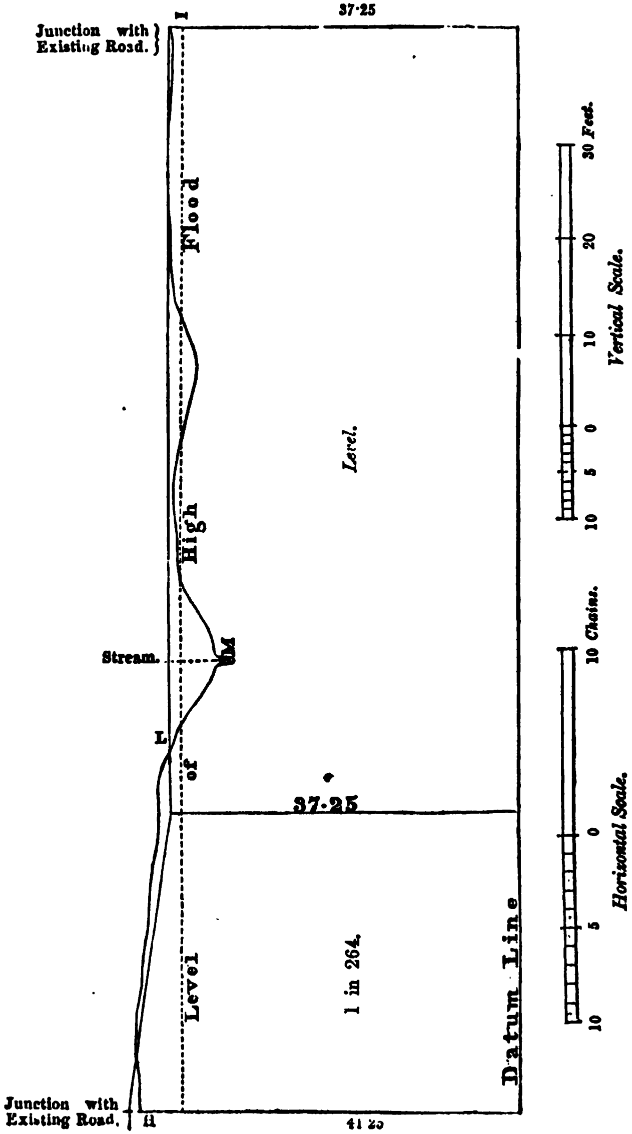

I
37·25
Junction with Existing Road.
River.
Stream.
River.
Stream.
K
Junction with Existing Road.
H
41.25
1 in 50
37·25
Datum Line
Level of High Floods
Level.
D
E
C
B
20 Feet.
10
0
5
10
Vertical Scale
10
5
0
Horizontal Scale.
10 Chains.

Fig. 7.


37·25
I
Junction with Existing Road.
Flood
High
of
L
Stream.
M
Level.
37·25
Level
1 in 264.
Datum Line
Junction with Existing Road.
II
41·25
30 Feet.
20
Vertical Scale.
10
0
5
10
10 Chains.
0
Horizontal Scale.
5
10

By reference to these drawings, it will be seen (fig. 5) that the straight line has to cross a stream at B, and the river twice at C and D; and also that it must pass from B to E, over a swamp or morass of such a nature that, if a solid embankment is formed, it is probable that a very large quantity of ground will be absorbed, beyond what the section would indicate; added to which, from the river being liable to be flooded, it will be necessary to form bridges with several capacious openings at those points where the intended road crosses the river. These disadvantages attending the more obvious route would induce the engineer to sketch out some other line, by which they would be avoided. And he would then have the levels taken, and the requisite information, to enable him to choose between the two.

The manner in which the sections should be drawn, and the information to be given upon them, are shown in figs. 6 and 7. In addition to which the following data should be obtained, and entered either in the survey field-book, or in the level-book.

At the point B (fig. 5) the line crosses a stream 8 feet in width and 1 foot deep; in flood this stream brings down a considerable quantity of water.

At the point C on the section the river is much narrower and not so deep as at other places, in consequence of a great portion of its waters finding a passage through the marshy ground on either side. Its width is 16 feet, and its depth 2 feet; the velocity of its current is 95 feet per minute; the height of its surface at the present time is 30·10 feet above the datum; and the angle of skew which the course of the stream makes with the line of the road is 62 degrees.

At the point D the river is 27 feet wide, and 2½ feet in depth; its velocity 87 feet per minute; the height of its surface above the datum 29·96 feet; and the angle of skew 49 degrees.

The ground from B to E is of a very soft boggy nature, and full of water.

The height to which the river has risen during the highest flood known, at the bridge at F on the plan, is 35 feet above the datum; the water-way at that time was 90 feet, and the sectional area of the openings through which the water then flowed was 550 square feet. The same flood at the lower bridge, at G on the plan, was 35·3 feet above

the datum; the water-way was 102 feet, and the sectional area nearly 600 square feet.

The deviation line only crosses one stream at M on the plan and section. The present width of this stream is 15 feet, and its depth 18 inches; but in times of flood it rises to the same height as the river, and brings down a large body of water. The present height of its surface above the datum is 31·25 feet, and the angle which its course makes with the line of road 85 degrees.

We have introduced the foregoing in order to show the kind of data which should be obtained by those engaged in taking the levels and survey for road-making.*

A cross section should also be taken of each of the existing roads near their junction with the intended road; the use of which is to show to what extent, if any, the levels of the existing roads might be altered, the better to suit that of the new road.

Possessed of the sections, figs. 6 and 7, we next proceed to lay down the line of the road, or, in other words, to determine the levels at which it shall be formed. As it is desirable that the road should always be dry, it should be at least a foot above the level of the flood; and if kept at 37·25 feet above the datum, which is the height of the existing road at I, we shall effect this object. Upon drawing a line at this level upon the section, we perceive that an embankment will have to be formed from the road at I, across the valley to the point where this line meets the ground at K, and that the remainder of the road from K to H will be in a cutting. Now the obvious principle, in arranging the levels of a road, would be so to adjust the cuttings and embankments that the ground taken from one should form the other. In the present instance, however, this is impossible, because the level of the road is determined by other circumstances, and necessitates the formation of a very long embankment with but very little cutting,

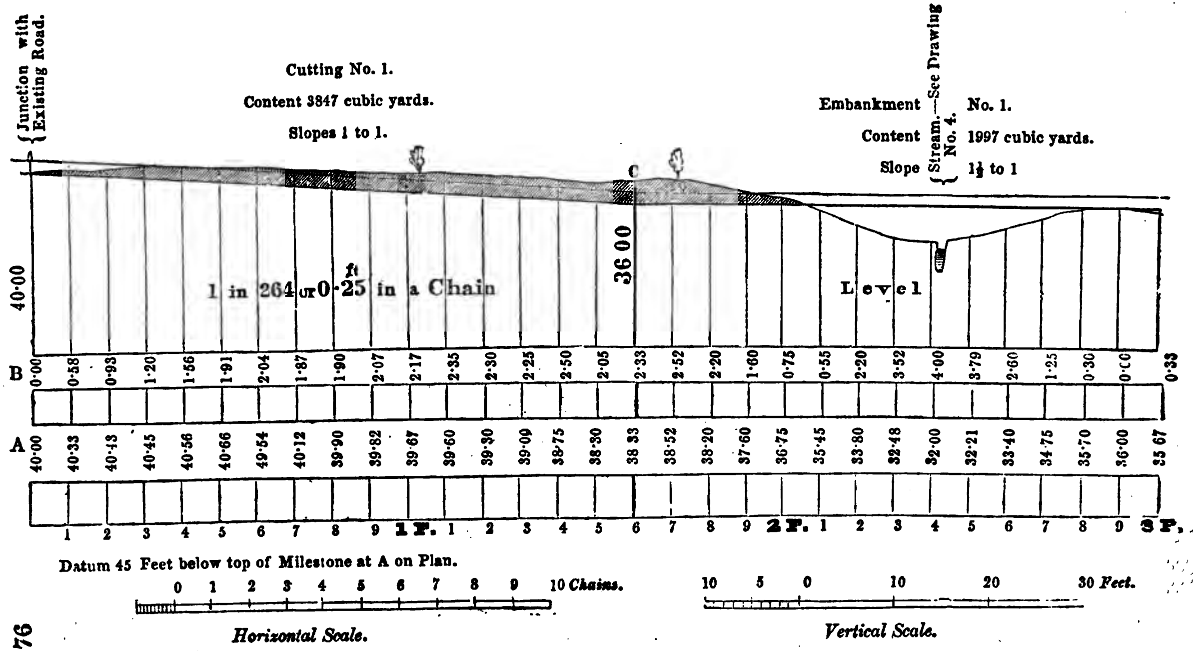
* The information relative to the rivers crossed, such as is given above, should always be obtained, in order that the bridges constructed over them may be adequate for the passage of the water brought down in time of floods.

therefore rendering it necessary for ground to be obtained from some other source, with which to form the embankment. In order to produce as much cutting as possible, the line should be kept at the same level as before until it becomes necessary to rise to attain the level of the existing road at H; if an inclination of 1 in 50 be given to this last part of the road, the distance at which the rise will commence will be 200 feet from H, the difference of level being 4 feet. We have therefore to add to the other disadvantages already mentioned, as belonging to the straight line of road, that of requiring the formation of a large embankment, and the necessity of making an excavation in some other place, to afford the earth for that purpose.

We will now examine the section of the deviation line, and see what improvement can be thereby effected. We must, as before, keep the level of the lowest portion of the road 37·25 feet above the datum; and if we draw a line at that level on the section, fig. 7, we shall find that the quantity of embankment is very much reduced, and that there will now be no difficulty in adjusting the cutting between H and L, so as exactly to afford the amount of filling required. A few trials will show that if the line be kept at the same level until within sixteen chains of H, and then carried up at a regular inclination, this object will be effected, and that the amount of cutting and embankment will be very nearly equal. This latter will therefore be the line which the engineer would select as the best; and having done so he would proceed to mark the course of the road on the ground, by driving a stake into the ground on its centre line at every chain (or 66 feet); he would then take very careful levels of the height of the ground at every one of these points, and at any intermediate point, where any undulation or change of level occurred, and wherever the level of the ground varied to any extent in a direction at right angles with the course of the road, he would take levels from which to make transverse or cross sections of the ground.

From these levels a working section should be made,

Fig. 8.


Junction with Existing Road.
Cutting No. 1.
Content 3847 cubic yards.
Slopes 1 to 1.
Embankment No. 1.
Content 1997 cubic yards.
Slope 1½ to 1
Stream.—See Drawing No. 4.
40·00
1 in 264 or 0·25 ft in a Chain
36 00
C
Level
B
0·00 0·58 0·93 1·20 1·56 1·91 2·04 1·87 1·90 2·07 2·17 2·35 2·30 2·25 2·50 2·05 2·33 2·52 2·20 1·60 0·75 0·55 2·20 3·52 4·00 3·79 2·60 1·25 0·30 0·00 0·33
A
40·00 40·33 40·43 40·45 40·56 40·66 49·54 40·12 39·90 39·82 39·67 39·60 39·30 39·09 38·75 38·30 38 33 38·52 38·20 37·60 36·75 35·45 33·80 32·48 32·00 32·21 33·40 34·75 35·70 36·00 35 67
1 2 3 4 5 6 7 8 9 1 F. 1 2 3 4 5 6 7 8 9 2 F. 1 2 3 4 5 6 7 8 9 3 F.
Datum 45 Feet below top of Milestone at A on Plan.
0 1 2 3 4 5 6 7 8 9 10 Chains.
Horizontal Scale.
10 5 0 10 20 30 Feet.
Vertical Scale.

having a horizontal scale of not less than five chains to the inch, and a vertical scale of 20 feet to the inch; a portion of the section plotted to these scales is shown in fig. 8; the level of the surface of the ground above the datum, at every chain at the points where stakes have been driven into the ground, should be figured-in on the section, as shown in the column A, and the depth of cutting or height of embankment, at the same points, should be given in another column, B. This last column is obtained by taking the difference between the level of the surface of the ground and the level of the road. It will be observed that upon the section there are two parallel lines drawn as representing the line of road; the upper line is intended to represent the upper surface of the road when finished, while the lower thick line represents what is termed the *formation surface*, or the level to which the surface of the ground is to be formed, to receive the foundation of the road; in the section we have made the formation 15 inches below the finished surface of the road, which will therefore be the thickness of the road itself. All the dimensions on the section are understood to refer to the formation level; and the height of the latter above the datum should be figured-in wherever a change in its rate of inclination takes place, which should be marked by a stronger vertical line being there drawn, as shown at C.

When the cuttings are of any depth, *trial* pits should be sunk at about every ten chains to the depth of the intended cutting, in order to ascertain the nature of the ground, and to determine the slopes at which the sides of the cutting would safely stand; and also at what slopes the same earth would stand when formed into the embankments. The cuttings and embankments should then be numbered on the section, and the slopes intended to be given to each stated upon the same. The contents of the cutting or embankment, that is, the number of cubic yards which will have to be moved for its formation, with the intended slope, should then be calculated and stated upon the section. The manner of calculating these quantities will be explained

in a subsequent chapter, on estimating the cost of the road.

Wherever rivers or streams are crossed, bridges or culverts must be introduced, and of these detail drawings should be prepared, and reference made to them on the working section.

A working plan should also be constructed on the same horizontal scale as the section, upon which the position of the center stakes should be shown; and on this plan the road should be drawn in of its correct width on its upper surface, and another line showing the foot of the slopes. The stakes on the plan should be numbered consecutively, to facilitate reference to any part of the line, and the width of land required at every stake should be calculated in the manner which we are about to describe, and entered in a kind of table, from which the width of land required for the purpose of the road may be ascertained at every chain. We will suppose that, in the present case, the finished width of the road itself is to be 40 feet, and that an additional 6 feet will be required on each side for the ditch and bank; we have then 26 feet as the side width of the road without any slopes, or where the road is on the same level as the ground, and we shall observe that in the following table, wherever there is no cutting or embankments (as at stakes Nos. 1 and 30), this is the width given in the fourth column. To find the heights at the other stakes we must add to the constant width (viz. 26 feet) the height of embankment or depth of cutting (as the case may be) multiplied by the ratio of the slope. Thus, in the first cutting, the ratio of the slopes being (as stated on the section) 1 to 1, we have simply to add the depths of the cutting at each stake to 26 feet, and we obtain the numbers given in the fourth column. After the 21st stake we leave the cutting, and the ratio of the slopes then becomes 1½ to 1; we have then to add one and a half times the height of the embankment, and we then in like manner obtain the numbers in the fourth column.

No. of stake on the plan.	Depth of cutting.	Height of embankment.	Distance of side fence from center line.	No. of stake on the plan.	Depth of cutting.	Height of embankment.	Distance of side fence from center line.
	Feet.	Feet.	Feet.		Feet.	Feet.	Feet.
1	0·00	—	26·0	17	2·33	—	28·3
2	0·58	—	26·6	18	2·52	—	28·5
3	0·93	—	26·9	19	2·20	—	28·2
4	1·20	—	27·2	20	1·60	—	27·6
5	1·56	—	27·6	21	0·75	—	26·8
6	1·91	—	27·9	22	—	0·55	26·8*
7	2·04	—	28·0	23	—	2·20	29·3
8	1·87	—	27·9	24	—	3·52	31·3
9	1·90	—	27·9	25	—	4·00	32·0
10	2·07	—	28·1	26	—	3·79	31·7
11	2·17	—	28·2	27	—	2·60	29·9
12	2·35	—	28·4	28	—	1·25	27·9
13	2·30	—	28·3	29	—	0·30	26·5
14	2·25	—	28·3	30	—	0·00	26·0
15	2·50	—	28·5	31	—	0·33	26·5
16	2·05	—	28·1				

After ascertaining the side widths as above, the next operation is to set out the same on the ground, driving in another stake at every chain at the correct distance on each side of the center one. A grip about 4 or 5 inches wide should then be cut from stake to stake, so as to mark both the center and sides of the road upon the ground by a continuous line. The side lines thus set out, it must be remembered, are not the foot of the slopes, but include 6 feet on each side for a bank and ditch; another stake should therefore be driven at every chain 6 feet within the outer stakes on each side, and another grip cut to mark the foot of the slopes.

A strong post should next be fixed into the ground upon the center line wherever a change in the inclination of the road takes place (as at the 17th stake in the present instance), upon which a cross piece should be placed at the intended height of the formation surface of the road, and

* The slopes here change from 1 to 1, to $1\frac{1}{2}$ to 1.

intermediate heights should be put up at such distances as will enable the workmen to keep the embankments to their proper level. In cuttings, pits must be sunk in a similar manner, at certain intervals, to the depth of the formation surface, to serve as guides to the excavators in forming the cutting.

CHAPTER II.

ON THE SECTION OF ROADS.

HAVING in the preceding chapter explained at length the objections which belong to inclined roads, and given rules for determining, with as much accuracy as the nature of the question will admit, the amount of resistance which they oppose to the haulage of vehicles, it will not be necessary in this place to say much on the longitudinal inclination, or *gradient*, as it is technically termed, of roads.

Where hills or gradients are necessary, they should be made as easy as possible; and, although with all hills a certain amount of additional power must be required to draw a carriage up them, so long as the inclination is within certain limits, the hilly road may be considered as safe as a level one would be. This limit depends upon the nature and condition of the surface of the road, and is attained in any particular case when the inclination of the road is made equal to the limiting angle of resistance for the materials composing its surface, that is, when it is such that a carriage once set in motion on the road would continue its descent without any additional force being applied. As soon as this limit is past, the carriage would descend with an accelerated velocity, unless the horses or other moving force were employed to restrain it; and, although in such a case the use of a drag, by increasing the resistance, would in a measure obviate the danger, yet the injury done to the

surface of the road by the use of the drag renders it desirable to dispense with it altogether. The following table, taken from the second volume of the Rudiments of Civil Engineering, shows the rate of inclination at which this limit is attained on the various kinds of roads mentioned in the first column. The values of the resistances on which this table is calculated are those given by Sir John Macneill, and already quoted at page 58.

Description of the road.	Force in lbs. required to move a ton.	Limiting angle of resistance.	Greatest inclination which should be given to the road.
		° ′	
Well-laid pavement	33	0 50	1 in 68
Broken stone surface on a bottom of rough pavement or concrete	46	1 11	1 in 49
Broken stone surface laid on an old flint road	65	1 40	1 in 34
Gravel road	147	3 45	1 in 15

The following table of gradients will be found of considerable value in laying out and arranging roads; the first column contains the gradient, expressed in the ratio of the height to the length; the two next, the vertical rise in a mile and a chain respectively; the fourth column, the angle (β page 61) of inclination with the horizontal; and the last column, the sine of the same angle, which is inserted for facilitating the calculation of the resistances occasioned by the gradient.

Gradient.	Vertical rise in a mile.	Vertical rise in a chain.	Angle (β) which gradient makes with the horizontal.	Sine of angle β.	Gradient.	Vertical rise in a mile.	Vertical rise in a chain.	Angle (β) which gradient makes with the horizontal.	Sine of angle β.
1 in 10	528·0	6·60	5° 42′ 58″	·09960	1 in 60	88·0	1·10	0° 57′ 18″	·01667
„ 11	480·0	6·00	5 11 40	·09054	„ 65	81·2	1·02	0 52 54	·01539
„ 12	440·0	5·50	4 45 59	·08309	„ 70	75·4	·94	0 49 7	·01429
„ 13	406·1	5·08	4 23 56	·07670	„ 75	70·4	·88	0 45 51	·01334
„ 14	377·1	4·71	4 5 14	·07128	„ 80	66·0	·82	0 42 58	·01250
„ 15	352·0	4·40	3 48 51	·06652	„ 85	62·1	·78	0 40 27	·01177
„ 16	330·0	4·12	3 34 35	·06238	„ 90	58·7	·73	0 38 12	·01111
„ 17	310·6	3·88	3 21 59	·05872	„ 95	55·6	·69	0 36 11	·01053
„ 18	293·3	3·67	3 10 47	·05547	„ 100	52·8	·66	0 34 23	·01000
„ 19	277·9	3·47	3 0 46	·05256	„ 110	48·0	·60	0 31 15	·00909
„ 20	264·0	3·30	2 51 21	·04982	„ 120	44·0	·55	0 28 39	·00833
„ 21	251·4	3·14	2 43 35	·04757	„ 130	40·6	·51	0 26 27	·00769
„ 22	240 0	3·00	2 36 10	·04541	„ 140	37·7	·47	0 24 33	·00714
„ 23	229·6	2·87	2 29 22	·04344	„ 150	35·2	·44	0 22 55	·00666
„ 24	220·0	2·75	2 23 10	·04163	„ 160	33·0	·41	0 21 29	·00625
„ 25	211·2	2·64	2 17 26	·03997	„ 170	31·1	·39	0 20 13	·00588
„ 26	203·1	2·54	2 12 2	·03840	„ 180	29·3	·37	0 19 6	·00556
„ 27	195·5	2·42	2 7 2	·03694	„ 190	27·8	·35	0 18 6	·00527
„ 28	188·5	2·36	2 2 5	·03551	„ 200	26·4	·33	0 17 11	00500
„ 29	182·1	2·28	1 58 34	·03448	„ 210	25·1	·31	0 16 22	·00476
„ 30	176·0	2·20	1 54 37	·03333	„ 220	24·0	·30	0 15 37	·00454
„ 31	170·3	2·13	1 50 55	·03226	„ 230	23·0	·29	0 14 57	·00435
„ 32	165·0	2·06	1 47 27	·03125	„ 240	22·0	·27	0 14 19	·00417
„ 33	160·0	2·00	1 44 12	·03031	„ 250	21·1	·26	0 13 45	·00400
„ 34	155·3	1·94	1 41 8	·02941	„ 260	20·3	·25	0 13 13	·00385
„ 35	150·9	1·88	1 38 14	·02857	„ 270	19·6	·24	0 12 44	·00370
„ 36	146·7	1·86	1 35 28	·02777	„ 280	18·9	·24	0 12 17	·00357
„ 37	142·7	1·78	1 32 53	·02702	„ 290	18·2	·23	0 11 51	·00345
„ 38	138·9	1·74	1 30 27	·02631	„ 300	17·6	·22	0 11 28	·00334
„ 39	135·4	1·69	1 28 8	·02563	„ 325	16·2	·20	0 10 35	·00308
„ 40	132·0	1·65	1 25 57	·02500	„ 350	15·1	·19	0 9 49	·00286
„ 41	128·8	1·61	1 23 50	·02438	„ 375	14·0	·18	0 9 10	·00267
„ 42	125·7	1·57	1 21 50	·02380	„ 400	13·2	·17	0 8 36	·00250
„ 43	122·8	1·53	1 19 56	·02325	„ 425	12·4	·16	0 8 5	·00235
„ 44	120·0	1·50	1 18 7	·02272	„ 450	11·7	·15	0 7 38	·00222
„ 45	117·3	1·47	1 16 24	·02222	„ 475	11·1	·14	0 7 14	·00210
„ 46	114·8	1·44	1 14 43	·02173	„ 500	10·6	·13	0 6 53	·00200
„ 47	112·3	1·40	1 13 8	·02127	„ 525	10·1	·12	0 6 33	·00191
„ 48	110·0	1·37	1 11 37	·02083	„ 550	9·6	·12	0 6 15	·00182
„ 49	107·7	1·35	1 10 9	·02040	„ 575	9·2	·11	0 5 59	·00174
„ 50	105·6	1·32	1 8 6	·01981	„ 600	8·8	·11	0 5 44	·00167
„ 55	96·0	1·20	1 2 30	·01818					

We next come to the subject of the width and transverse form which should be given to roads. As regards the first, the width to be given to the road, we should certainly recommend a wide road; it is an error to suppose that the cost of repairing a road depends entirely upon the extent of its surface, and consequently increases just as we increase its width; the cost per mile of road depends more upon the extent and nature of the traffic, and unless extremes be taken, it may be asserted that the same quantity of material would be necessary for the repair of a road, whether wide or narrow, which was subjected to the same amount of traffic; with the narrow road, the traffic, being confined more to one track, would wear the road more severely than when spread over a larger surface; the expense of spreading the material over the wider road would be somewhat greater, but the cost of the materials might be taken as the same. One of the advantages of a wide road is, that the wind and sun exercise more influence in keeping its surface dry. The first cost of a wide road is certainly greater than that of a narrow one, and that nearly in the ratio of its increased width.

For roads situated between towns of any importance, and exposed to much traffic, the width should certainly not be less than 30 feet, besides a footpath of 6 feet; and in the immediate vicinity of large towns and cities, the width should be still further increased. No specific rules can, however, be given for the width in such situations; experience will soon show what width is requisite in any given situation.

The form to be given to the cross section of a road is a subject of much importance, and one upon which much difference of opinion exists. Some advocate a considerable curvature in the upper surface of the road, with the view of facilitating the drainage of its surface; while others (and that the majority) are averse to a road being much curved, for reasons which we will presently state. Again, it is the practice of some to form the road on a flat surface transversely; while others propose giving a dip to the

formation surface each way from the center, on the supposition that the drainage of the road will be thereby facilitated.

Now it must be obvious to all, that the only advantage resulting from curving the transverse section of the road is, allowing the water, which would otherwise collect upon its surface, to drain freely off into the side ditches. It has been urged by some that, in laying on fresh material upon a road, it is necessary to keep the center much higher than the sides; because, in consequence of the majority of carriages using the center of the road, that portion will wear quicker than the sides, and, unless made originally much higher, when so worn it will necessarily form a hollow or depression, from which the water cannot drain. Now it is entirely overlooked by those who advance this argument, that the only reason why carriages use the center in preference to the sides of a road, is *because of its rounding form*, it being only in that situation that the carriage stands upright; if the road were comparatively flat, every portion would be equally used; but on very convex roads, the center is the only portion of the road on which it is safe to travel. On this subject Mr. M'Adam remarks, in giving evidence before a committee of the House of Commons,* "I consider a road should be as flat as possible with regard to allowing the water to run off it at all, because a carriage ought to stand upright in travelling as much as possible. I have generally made roads three inches higher in the center than I have at the sides, when they are eighteen feet wide; if the road be smooth and well made, the water will run off very easily in such a slope." And, in answer to the question, "Do you consider a road so made will not be likely to wear hollow in the middle, so as to allow the water to stand, after it has been used for some time?" he replies,—"No; when a road is made flat, people will not follow the middle of it as they do when it is made extremely convex. Gentlemen will have observed that in roads very convex, travellers generally follow the track in the middle,

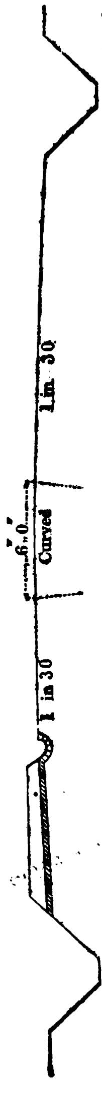
* Parliamentary Report on the Highways of the Kingdom, 1819, p. 22.

which is the only place where a carriage can run upright, by which means three furrows are made by the horses and the wheels, and water continually stands there; *and I think that more water actually stands upon a very convex road than on one which is reasonably flat.*" And on the same subject, Mr. Walker remarks,* "A road much rounded is dangerous, particularly if the cross section approaches towards the segment of a circle, the slope in that case not being uniform, but increasing rapidly from the nature of the curve, as we depart from the middle or vertical line. The over-rounding of roads is also injurious to them, by either confining the heavy carriages to one track in the crown of the road, or, if they go upon the sides, by the greater wear they produce, from their constant tendency to move down the inclined plane, owing to the angle which the surface of the road and the line of gravity of the load form with each other; and, as this tendency is perpendicular to the line of draught, the labour of the horse and the wear of the carriage wheels are both much increased by it."

The drainage of the surface of the road is then the only useful purpose which will be answered by making it convex; and even this in but a very imperfect manner, in consequence of the irregularities and roughness which we find even in the best roads. The surface of a road is much more efficiently drained by a small inclination in the direction of its length, than by a much greater transverse slope; on this subject Mr. Walker has very justly remarked,† "Clearing the road of water is best secured by selecting a course for the road which is not horizontally level, so that the surface of the road may, in its longitudinal section, form, in some degree, an inclined plane; and when this cannot be obtained, owing to the extreme flatness of the country, an artificial inclination may generally be made. When a road is so formed, every wheel-track that is made, being in the line of inclination, becomes a channel for

* Parliamentary Report, 1819, p. 49. † Ib. p. 48.

FIG. 9.



carrying off the water much more effectually than can be done by a curvature in the cross-section or rise in the middle of the road, without the danger or other disadvantages which necessarily attend the rounding a road much in the middle. I consider a fall of about an inch and a half in ten feet to be a minimum in this case, if it is attainable without a great deal of extra expense." While, then, the advantages attending the extreme convexity of roads is so small, the disadvantages are considerable; on roads so constructed, vehicles must either keep upon the crown of the road, and so occasion an excessive and unequal wear of its surface, or use the sides, with the liability of being overturned. The evidence of coach-masters and others, taken before the Committee of the House of Commons, and appended to the report from which we have already quoted, quite bears out the view here taken, and shows that many accidents, and much danger, have arisen from the practice of forming roads with an excessive amount of convexity.

In making the above remarks, we must be understood as only disapproving of the practice (which has been but too prevalent) of forming roads with cross sections rounding in an extreme degree, and not as advocating a perfectly, or nearly, flat road, as many, who have fallen into the opposite error, have done. We should recommend, as the best form which could be given to a road, that it cross section should be formed of two straight lines inclined at the rate of about 1 in 30, and united at the center or crown of the road by a segment of a circle, having a radius of about 90 feet. This form of section is shown in fig. 9, and the rate of inclination there given is quite sufficient to keep the surface of a road drained, provided it is in good order and free from ruts; if such is not the case,

no amount of convexity which could be given to the road would be of any avail, as the water would still remain in the hollows or furrows.

The form of cross section here suggested is equally adapted to all widths of road, as the straight lines have merely to be extended at the same rate of inclination, until they meet the sides of the road.

The foregoing remarks apply only to the exterior or upper surface of the finished road; with regard to the form which should be given to the bed upon which the road is to be formed, a similar difference of opinion exists as to whether it should be flat or rounding. In this case we are of opinion that, except where the surface upon which the road has to be formed is a strong clay or other soil impervious to water, no benefit will result, as far as drainage is concerned, in making the formation surface or bed of the road convex. It should be borne in mind that, after the road materials are laid upon the formation surface, and have been for some time subjected to the pressure of heavy vehicles passing over them, they become, to a certain extent, intermixed; the road materials are forced down into the soil, and the soil works up amongst the stones, and the original line of separation becomes entirely lost. If the surface upon which the road materials were laid were to remain a distinct flat surface, perfectly even and regular, and into which the road materials could not be forced, then it would be of use to give such an inclination to it as would allow any water which might find its way through the crust or covering of the road to run off to the sides of the same; although, even then, it would have to force a passage between the road materials and the surface on which they rest; such is, however, as we have already remarked, far from being the case; and, therefore, we hold that, unless under peculiar circumstances, no water which had found its way through the hard compact service of the road itself would be arrested by the comparatively soft surface of its bed, and carried off into the side ditches, whatever the slope which might be given to it. While, however, we

believe that, as far as drainage is concerned, it is useless to form the bed or formation surface of the road with a transverse slope, we should, nevertheless, give it the same, or nearly the same, form as that which we have just recommended for its upper finished surface; with the object of making the two surfaces parallel, and so giving an equal depth of road material over every portion of the road. In this respect we do not agree with some road-makers, who not only recommend a less depth of road materials to be put on the sides than on the center of the road, but further advise that an inferior description of material should there be employed. On this subject we cannot do better than quote the following remarks, which Mr. Hughes has made on this point, and which are very much to the purpose:*—"A very common opinion is, that the depth of material in the center of the road should be greater than at the sides, but, for my part, I have never been able to discover why the sides of the road should be at all inferior to the middle in hardness and solidity. On the contrary, it would be a great improvement in general travelling, if carriages could be made to adhere more strictly to the rule of keeping the proper side of the road; and the reasonable inducement to this practice is, obviously, to make the sides equally hard and solid with the center. In many roads, even where considerable traffic exists, the only good part of the road consists of about eight or ten feet in the center, the sides being formed with small gravel quite unfit to carry heavy traffic; and the consequence is, that the whole crowd of vehicles is forced into the center track of the road; thus at least doubling or trebling the wear and tear which would take place if the sides were, as they ought to be, equally good with the center. Another mischievous consequence is, that when it becomes necessary to repair the center of the road, the carriages are driven off the only good part on to the sides, which consist of weak material, and are often even dangerous for the passage of heavily-laden stage

* The Practice of Making and Repairing Roads, by Thomas Hughes. 1838, p. 12.

coaches. On the other hand, if equal labour and materials be expended on the whole breadth of the road, it is evident that the wear and tear will be far more uniform; and when any one part requires repair, the traffic may with safety be turned on to another part. Hence, I should always lay on the same depth of material all over the road: and this alone will of course render it necessary to curve the bed of the road."

Too much attention cannot be paid to the drainage of roads, both as regards their upper surface, and that of the substratum on which they rest. To assist the surface drainage, the road should be formed with the transverse section which we have shown in fig. 9, and on each side of the road a ditch should be formed of sufficient capacity to receive all water which can fall upon the road, and of such a depth, and with a sufficient declivity, to conduct the same freely away. When footpaths have to be constructed on the sides of the roads, a channel or watercourse should be formed between them, and small drains, formed of tiles or earthern tubes (such as are used for underdraining lands), should be laid under the footpath, at such a level as to take off all the water which may collect in this channel, and convey it into the ditch. In the best-constructed roads, these side channels should be paved with flints or pebbles; the drains under the footpath should be introduced about every 60 feet, and should have the same inclination (viz. 1 in 30) as we recommended for the sides of the road, as shown in fig. 9: a greater inclination would be objectionable. It is a very frequent mistake to give too great a fall to small drains, the only effect of which is, to produce such a current through them as to wash away or undermine the ground around them, and ultimately cause their own destruction. When a drain is once closed by any obstruction, no amount of fall which could be given to it would again clear the passage; while a drain, with a considerable current through it, would be much more likely to be stopped from foreign matter being carried into it, which a less rapid stream could not have transported there.

In the case of a road whose surface was drained in the way which we have just described, and whose surface was composed of proper materials in a compact state, very little water would find its way through to the substratum; with some descriptions of soil, however, it would be desirable to adopt means for maintaining the foundation of a road in a dry state; as, for instance, when the surface was a strong clay through which no water could percolate, or when the ground beneath the road was naturally of a soft, wet, or peaty nature. Under such circumstances it would be desirable to provide for its proper drainage, by a species of underdrainage. As soon as the surface of the ground had been formed to the level intended for the reception of the road materials, trenches should be formed across the road, from a foot to eighteen inches in depth, and about a foot wide at the bottom, the sides being sloped as shown in fig. 10. The distances at which these drains ought to be formed would depend in a great measure on the nature of the soil; in the case of a strong clay soil, or one naturally very wet, there should be one about every 20 feet, and this

FIG. 10.

Formation Surface.

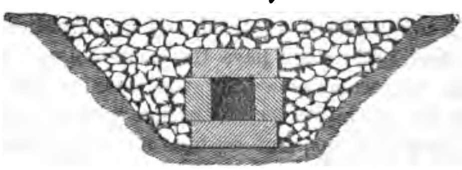
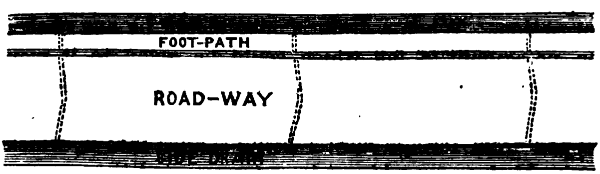


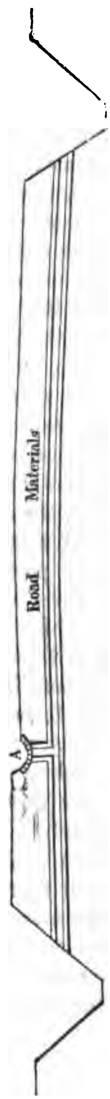
FIG. 11.



distance might be increased as the ground became firmer or drier. In these trenches, a drain not less than 4 inches square internally should then be formed either of old bricks, drain-tiles, flat stones, or in any other mode used for underdrains, and the remainder of the trench should be filled with coarse stones free from all clay or dirt, in the manner shown in fig. 10. Of course these drains must have a fall given them from the center of the road into the ditches on either side; an inclination of 1 in 30 will be sufficient. When the road is level in the direction of its length, these drains should run straight across, but on those portions of the road which were inclined, the drains should be formed, as shown on the plan, fig. 11, somewhat in the form of a very flat v, the point being in the center of the road, and the drains making an acute angle with the line of the road, in the direction in which it falls; the amount of this angle should not be greater than is shown in fig. 11.

When a road with footpaths is underdrained in the manner which we have just described, it will not be necessary to form drains from the side channel under the footpath into the ditch, as shown in fig. 9, but merely to carry up a little shaft, constructed in the same way as the drain, from the drain to the channel, covering the same with a small grating to prevent leaves or other substances, which might choke the drain, being carried into it. This method of forming the drains is shown at A in fig. 12.

Fig. 12.



CHAPTER III.

ON THE CONSTRUCTION OF ROADS.

WE next proceed to the mode which should be pursued in the construction of the road itself, but before doing so, we must say a few words on the foundation upon which the road materials are to be placed. On this subjct, again, a great difference of opinion exists. By a few, amongst whom we may mention Mr. M'Adam, it has been maintained that a yielding and soft foundation for a road is better than one which is firm and unyielding; and he has gone so far as to say that he "should rather prefer a soft one to a hard one," and even a bog, "If it was not such a bog as would not allow a man to walk over it."* The principles upon which this opinion was founded were, that the road on the soft foundation being more yielding or elastic, the materials of which the covering of the road was formed would be less likely to be crushed and worn away by the passage of a heavy traffic over them than when placed on a hard solid. The contrary opinion is, however, that which has received the largest number of advocates, and is that which we ourselves hold; and we feel assured that there is no more general cause of bad roads than their being formed upon a soft foundation. We would most strongly urge the necessity of securing a firm, solid, and dry substratum for the road materials to rest upon; and we are quite satisfied that, however good the materials themselves may be, and however much care may be bestowed upon the manner in which they are put on, unless a good foundation has been previously prepared, the whole of the materials and labour will be only thrown away. The outer surface of the road should be regarded merely as a covering to protect the actual working road beneath, which latter should be sufficiently firm and substantial to support

* Parliamentary Report, 1819, p. 23.

the whole of the traffic to which it may be exposed. The real use of the road materials laid over it should be only to protect this actual road from being worn and injured by the horses' feet and the wheels, or from the action of the weather. And this lower, or *sub-road*, as it may be called, being once properly constructed, would last for ever, merely the outer case or covering requiring to be renewed from time to time, so as always to preserve a sufficient depth for the protection of the sub-road.

We may very conveniently class roads, according to the manner in which their foundation is formed, as follows:—

1st. Roads having no artificial foundation, but in which the covering materials are laid on the ground.

2nd. Roads having a foundation of concrete.

3rd. Roads having a paved foundation.

And each of these might be again divided according to the kind of material employed as a covering.

The first of these classes will certainly contain by far the largest proportion of the roads in this country. But it should only be employed in cases where the importance of the road is not sufficient to warrant any large expenditure, and when the amount of traffic to be anticipated is small; for we are certainly of opinion that is a very mistaken economy which would incur a large permanent annual outlay for repairs, to save in the original cost of constructing the road, and we are satisfied that, in this sense, a road with a paved or concrete foundation will always be found less expensive than one formed without such a foundation.

Where, however, circumstances may render it necessary to construct a road upon the natural surface of the ground, every care should be taken to make it as solid as possible. If the ground is at all of a soft or wet nature, deep ditches should be cut on each side of the line of the road, and cross underdrains should be formed in the manner already described at page 91. And where the ground is very soft, a layer of faggots or brushwood, from 4 to 6 inches in depth, should be laid over the surface of the ground before laying on the road materials. In cases of embankments, or where

the ground under the road has been recently deposited, the surface should be either rolled or *punned*, that is, beaten with heavy beetles, so as to ensure as great a degree of solidity as possible. The same mode of proceeding should be followed, even where it is intended to form either a paved or concrete foundation, for, as we before remarked, too much care cannot be bestowed on that part of the road.

The employment of concrete composed of gravel and lime was first proposed by Mr. Thomas Hughes, and the following remarks upon its use are quoted from his work on roads.*

"The use of lime concrete, although an introduction of modern times, and certainly one of rather a novel character, derives its real origin from a very remote period. We have indisputable evidence that the Romans, in constructing their military ways, particularly in France, adopted the practice of forming a concrete foundation composed of gravel and lime, on which also they placed large stones as a pavement. The consequence of a construction so solid has been, that, in many parts of Europe, the original bed or crust of the Roman roads is not at the present day entirely worn down, even after a lapse of fifteen centuries.

"With the view of affording a modern example in which lime concrete has been used, I would refer to the Brixton-road, where a concrete composed of gravel and lime has been recently applied by Mr. Charles Penfold, surveyor to the trust. In this case the proportion of gravel to lime is that of four to one. The lime is obtained from Merstham or Dorking, and before being used is thoroughly ground to powder. The concrete is made on the surface of the road, and great care taken, when the water is added, that every particle of the lime is properly slacked and saturated. The bed of concrete having been spread to the depth of 6 inches over the half breadth of the road, the surface is then covered over with 6 inches of good hard gravel or broken

* The Practice of Making and Repairing Roads, p. 44.

stone, and this depth is laid on in two courses, of 3 inches at a time, the first course being frequently laid on a few hours after the concrete has been placed on the road. The carriages, however, are not on any account allowed to pass over it until the concrete has become sufficiently hard and solid to carry the traffic without suffering the road material to sink and be pressed into the body of concrete. On the other hand, the covering of gravel is always laid on before the concrete has become quite hard, in order to admit of a more perfect binding and junction between the two beds than would take place if the concrete were suffered to become hard before laying on the first covering. The beneficial effect arising from the practice of laying on the gravel exactly at the proper time is, that the lower stones, pressed by their own weight, and by those above them, sink partially into the concrete, and thus remain fixed in a matrix, from which they could not easily be dislodged. The lower pebbles being thus fixed, and their rolling motion consequently prevented, an immediate tendency to bind is communicated to the rest of the material—a fact which must be evident, if we consider that the state called binding, or rather that produced by the *binding*, is nothing more than the solidity arising from the complete fixing and wedging of every part of the covering, so that the pebbles no longer possess the power of moving about and rubbing against each other. It is found that, in a very few days after the first layer has been run upon, the other, or top covering, may be applied; and, shortly afterwards, the concrete, and the whole body of road material, becomes perfectly solid from top to bottom. The contrast thus presented to the length of time and trouble required to effect the binding of road materials where the whole mass is laid on loose, is alone a very strong recommendation in favour of the concrete.

"The experiment of using concrete on the Brixton-road, although not at present on a very extensive scale, has been tried under circumstances very far from being favourable, and on a part of the road which had hitherto baffled every

attempt to make it solid. Since the concrete has been laid down, however, there is not a firmer piece of road in the whole trust; and from the success of this and other trials made by Mr. Penfold, but which I have not seen, I believe it is his intention to recommend it, in a general and extensive way, to several trusts under whom he acts."

Mr. Penfold, himself, states the result of an experiment made by him upon the Walworth-road. "It was raised by nine inches of concrete, and six of granite and Kentish rag-stone mixed; and in some parts it was covered by rag and flints. The improvement is so great, with respect to the draught, and so desirable with respect to the saving in the annual repair, that the trust have directed it to be applied to upwards of two miles of road upon which the greatest traffic exists."*

One of the principal advantages attending the employment of concrete as a foundation for roads is, that in this manner a good and solid road may be made with materials, such as round pebbly gravel, which, in any other mode of application, would be but very ill suited to the purpose, and would form a very imperfect road. And this description of gravel is that which is by far the most frequently met with. The gravel selected for this purpose should be free from any kind of dirt, clay, or other impurity, and should consist of stones and sand, mixed in about such proportions that the latter would just fill the interstices of the former. The gravel should then be mixed with the proper quantity of ground unslacked lime—in ordinary cases five or six parts of gravel and one of lime will be found to answer; after which, sufficient water being added to effect the slacking of the lime, the whole should be quickly, but thoroughly, mixed up, and then immediately thrown into place, and trimmed off at once to the proper form intended to be given to its upper surface; the first layer of broken stones or screened gravel, as the case may be, should then, as Mr.

* A Practical Treatise on the best Mode of Making and Repairing Roads, by Charles Penfold, p. 31.

Hughes directs, be put over just at that period when the concrete is about to set, and which time a very few trials will suffice to determine.

The other mode of forming an artificial foundation to which we have alluded, was introduced by Mr. Telford, and consists in forming a rough pavement on the top of the formation-surface, which is afterwards covered by the road materials. The following is an extract from one of Mr. Telford's specifications for a portion of the Holyhead-road:—"Upon the level bed prepared for the road materials, a bottom course or layer of stones, is to be set by hand, in form of a close firm pavement; the stones set in the middle of the road are to be 7 inches in depth: at 9 feet from the center, 5 inches; at 12 from the center, 4 inches; and at 15 feet, 3 inches. They are to be set on their broadest edges lengthwise across the road, and the breadth of the upper edge is not to exceed 4 inches, in any case. All the irregularities of the upper part of the said pavement are to be broken off by the hammer, and all the interstices to be filled with stone chips, firmly wedged or packed by hand, with a light hammer; so that when the whole pavement is finished, there shall be a convexity of 4 inches in the breadth of 15 feet from the center."*

The stone which Telford employed for this purpose, was generally such as would have been totally unfit for most other purposes, both on account of its inferior quality, and from the smallness of its dimensions. In comparing the relative merits of these two methods of forming the foundations of roads, due regard must be had to the nature of the materials found in the locality in which the road has to be formed. Where stone is plentiful, and easily procured, the paved foundation would be the best; while, in a neighbourhood where stone was scarce, but gravel and lime abundant, the preference must be given to the concrete foundation.

The foundation of the road having been prepared, in

* Sir H. Parnell on Roads, p. 133.

either of the modes which we have described, the next proceeding is, to form a firm and compact covering to protect the foundation from being injured, and to form a smooth surface for carriages to travel upon. Now, in order to fulfil this double office efficiently, the materials of which this covering is composed should possess the property of becoming quickly united into one solid mass, whose surface should be smooth and hard, and at the same time not liable to be broken to pieces, or ground into dust, by the wheels or the horses' feet. All the materials which have been applied for this purpose belong to one of two kinds; either angular fragments of broken stone of different sorts, or gravelly pebbles, more or less round: and it is essential to the formation of a good road that the distinction here pointed out be kept always clearly in view, because a totally different mode of proceeding must be adopted to form a perfect road with these two classes of material. The want of attention to the distinction which we here point out has led to much discussion and misapprehension upon the subject of employing clay, chalk, or other material, as a binding upon roads.

If the materials of which the road covering is to be formed are in angular masses, then no binding of any description is requisite; as it is found that they quickly become united by dovetailing, as it were, amongst each other, and that in a much firmer manner than they would become by the use of any kind of artificial cement.

When, however, the stones, instead of being angular, are round and pebbly, like gravel stones, it then becomes necessary to mix with them just sufficient foreign matter, of a binding nature, as will serve to fill up the interstices between the stones, which otherwise would roll about, and prevent the road from becoming solid.

We have, then, two methods of cementing or solidifying the surface of a road: one, by the mechanical form of the materials themselves forming a species of bond; the other, by the use of some cementing or binding matter. And in comparing the relative merits of the two, the preference

must certainly be given to the former, that in which the stones are caused to unite from their dovetail form, without the use of any cementing material. The principal reason for giving this preference is, that roads formed with stones so united, are not affected materially by wet or frosty weather; whereas, those whose surfaces are composed of pebbly stones united by some cementing material become loose and rotten under such circumstances, from the cementing material becoming softened by the wet, and reduced to a loose pulverulent state by subsequent frost.

The first method, that of forming the road-covering entirely with angular pieces of stone, without any other material, was first strongly recommended by Mr. M'Adam, and all subsequent experience has shown its superiority over every other which has been employed. The most important quality in stone for road-making is *toughness;* mere hardness without toughness is of no use, as such stone becomes rapidly reduced to powder by the action of the wheels. Those stones which have been found to answer this purpose best are, the whinstones, basalts, granites, and beach pebbles. The softer descriptions of stone, such as the sandstones, are not fitted for this purpose, being far too weak to resist the crushing action of the wheels. The harder and more compact limestones may be employed; but, generally speaking, the limestones are to be avoided, in consequence of their great affinity for water, which causes them, in frosty weather, which has been preceded by wet, to split up into a pulverulent state, and destroys the solidity of the road.

Next in importance to the quality of the stone is its proper preparation; this consists in reducing it to angular fragments of such a size that they will pass freely through a ring of 2½ inches in diameter in every direction; that is, that their largest dimensions shall not exceed that measure.

The stone, having been thus prepared, should then be evenly spread over the surface prepared for the foundation of the road, to the depth of about 6 inches; and the road

should then be opened for traffic. In Mr. Telford's specifications, he usually directed that on the top of this coating of broken stone a layer of good clean gravel, about an inch and a half in depth, should be spread before throwing the road open for use. The reason for this practice was, to lessen the extreme unevenness of the surface, and to render the road more pleasant to pass over when first opened; it would be better, however, for the public to put up with the temporary inconvenience of a rough road, because the gravel does a permanent injury to the road, and lessens in a considerable degree the property which the stones possess of uniting into a compact solid mass.

Broken stone, being so superior to gravel for the purpose of road-making, should always be employed where it can be easily obtained. There are, however, many situations in which gravel is the only available material. The quality of gravel varies so considerably, that while some kinds may, when properly prepared, form a very excellent road, others may be entirely worthless; of this last are those kinds of gravel the stones composing which are of the sandstones and flints, for even these last, although hard, are so excessively brittle as to be immediately crushed by the passing of the wheels over them. The gravel when taken from the pit should be passed over a screen which will allow all stones less than three quarters of an inch to pass through it, and the fine stuff, or *hoggin*, as it is technically termed, thus obtained, should be reserved for forming the footpaths; the remainder, which has not passed through the screen, should have all the stones whose greatest dimension is more than 2½ inches removed and broken, and it would be desirable that these broken stones should be reserved for the upper layer. In screening the gravel, especially as it first comes out of the pit, a certain portion of loam will generally be found to adhere to the stones, and this should by no means be separated from them, for, as we have already mentioned, although angular broken stones require no extraneous substance to cause them to bind, the case is different with the pebbles, of which most gravel is composed,

which require a certain amount of loam, clay, or chalk, to fill up the interstices between the stones, and prevent them from being rolled about, as they otherwise would be. On this subject, Mr. Hughes has made some observations so much to the purpose that we cannot do better than quote them:*—"In laying on this upper covering many surveyors commit a great error in not making a distinct difference between angular or broken stones and those rounded smooth pebbles of which gravel is usually composed. The former cannot be too well cleaned before being laid on the road, because, even when entirely divested of all earthy matter, they soon become wedged and bound closely together when the pressure of carriages comes upon them. But the case is different with the smooth round surfaces of gravel; for if this material be entirely cleaned by means of washing and repeated siftings, the pebbles will never bind, until in a great measure they become ground and worn down by the constant pressure and rubbing against each other. Before this takes place the surface of the road must be considerably weakened, and will in fact be incapable of supporting the pressure of heavy wheels, which consequently sink into it, and meet with considerable resistance to their progress. Under these circumstances, it seems that the practice of too scrupulously cleaning the rounded pebbles of gravel must be decidedly condemned; and the question then arises, to what extent should the cleaning process be dispensed with; or, in other words, what proportion of the binding material found in the rough gravel, as taken out of the pit, should be allowed to remain in the mass intended to be placed on the road? * * * A long course of experience, accompanied by attentive observations on these details in the practice of road-making, has convinced me that it is much better and safer, as a general rule, to leave too much of the binding material in the gravel than to divest it too completely of this substance. When the gravel is placed on a road without being sufficiently

* The Practice of Making and Repairing Roads, p. 15.

cleaned, the constant wear and tear, aided by the occurrence of wet weather, causes the harder material or actual gravel to be pressed close together; and the surplus of soft binding material remaining after the interstices between the pebbles are filled up being then forced to the top, and usually mixed with water, becomes mud, and according to the usual practice should be scraped to the sides of the road. When this has been done, the surface is usually firm and solid; because the hard gravel below the mud has become perfectly bound, without, at the same time, being broken or ground to pieces. Suppose, next, a road covered with gravel too much cleaned, where it is evident that the destruction of the gravel will continue until it becomes broken into angular pieces, and a sufficient quantity of pulverised material has been formed to hold the stones in their places and thus to effect the binding of the mass. I need hardly say, that the deterioration thus occasioned to the road is an evil of much more importance, and one much more to be avoided, than that occasioned by employing stones not sufficiently cleaned. Regardless of all this, however, it is the practice of many road-surveyors to insist that all gravel of whatever quality shall be rendered perfectly clean by repeated siftings, and even by washing, until it becomes entirely divested of all that may properly be considered the binding part of the material."

The gravel, when thus prepared by screening, should be laid on and spread to a uniform depth of not more than 6 inches over the whole road, which may then be thrown open to the use of the public: particular care and attention, however, is required to be given to new roads when first opened for traffic; a sufficient number of men should be employed to keep every rut raked in the moment it appears, and guards or fenders should be placed on the road, to oblige the vehicles to pass over every part of its surface in turn. If these precautions are not taken, years may elapse before the road attains a firm condition; and many roads have been permanently ruined through the want of proper attention when first used. When ruts are

once formed, every succeeding vehicle using the road keeps in the same track, deepening and increasing the rut, which in wet weather becomes filled with water, which, having no other means of escape, slowly penetrates the sides and bottom of the rut, rendering them so soft as to be still further acted upon by each succeeding carriage. These ruts once formed, a much larger outlay is required to repair the injury than would have prevented its occurrence, besides the inconvenience, danger, and expense to the public, in being obliged to travel on a road when in such a condition.

Amongst the substances which we mentioned might be mixed with *clean* gravel to enable it to bind was chalk. Now we think it necessary to say a few words on the use of chalk on roads, as much misapprehension exists on the subject, and many roads have been ruined from its improper use. There are two modes in which chalk may be advantageously employed in the construction of roads. It may be laid in the *very bottom* of the road, to form the foundation; *but it must be at such a depth as to be entirely beyond the influence of frost,* otherwise it will quickly destroy the road, for chalk has a very powerful affinity for water, or rather, to speak more correctly, capillary attraction for it, in consequence of which it readily absorbs all the moisture which finds its way through the road covering; and herein consists its value if judiciously applied, for the water thus absorbed would otherwise have penetrated to the foundation of the road and rendered it soft. If, however, the chalk be placed within the influence of frost, the water, which is only mechanically held by the chalk, will, in the act of congealing, expand, and by so doing rend the chalk into a thousand fragments, and reduce it in fact to a pulverulent state, which the succeeding thaw changes into a soft paste or mud. The other purpose for which chalk may be employed is, as we have already mentioned, to be mixed with gravel in order to make it bind; in using chalk, however, for this purpose, it should be borne in mind that it is only required when the gravel is perfectly clean and free

from other binding matter; the mixing it with gravel already containing sufficient clay or loam is not only useless, but is positively injurious; and, even when the gravel is of such a nature as to require being mixed with chalk, great care should be taken not to add too much, for it is not with chalk as with the loam or clay, with which gravel is naturally combined; the latter, generally speaking, possesses little power of absorbing water, but the superabundant chalk would soon be reduced to the state of a soft paste by the action of the weather, in the manner which we have just described. Chalk, therefore, if used as a binding material with gravel on the surface of roads, *should be reduced to a state of powder, and should be perfectly and thoroughly mixed with the gravel before the latter is spread on the road.*

We would also remark here, that, although we have recommended the use of bushes or bundles of faggots, to form the foundation of roads over very soft or boggy ground, they should only be employed in such situations, and at such a depth below the surface, as will ensure their always being damp; for when in a situation where they would be alternately wet and dry, they would quickly become rotten, and form a soft stratum beneath the road.

CHAPTER IV.

ON REPAIRING AND IMPROVING EXISTING ROADS.

THE improvement of existing roads may be divided into two distinct branches; namely, the improvement of their general course and levels, and the improvement of the materials of the road. The first of these consists in the application of the principles which we have laid down for

the construction of new roads to the altering of those already existing, and consists generally in straightening their course by avoiding unnecessary curves and bends; improving their levels by either avoiding or cutting down hills, and embanking valleys; increasing their width, where requisite, and rendering it uniform throughout. As these principles are the same in both cases, and their application has been already explained at length, it will be unnecessary to recapitulate them here.

It is to the second class of improvements that we are about to direct attention; namely, that of the surface of the road; and this consists in bringing its transverse section to the form which we have shown in fig. 9, page 86, filling up all ruts, cleansing and deepening, if necessary, the side ditches, cutting down trees or hedges by the side of the road, removing mud-banks which but too often exist on the road-sides, and putting proper materials on its surface.

Of all these, the most important to explain, because the most difficult to effect, and the least generally understood, is the method by which to improve the condition of the surface of the road. With most surveyors the universal remedy for a bad road is to heap on fresh material; whereas, as Mr. M'Adam has very justly observed,* "Generally, the roads of the kingdom contain a supply of materials sufficient for their use for several years, if they were properly lifted and applied." Generally speaking, the cause of bad roads is their imperfect transverse form, and the improper manner in which the road materials are used. The remedial measures to be adopted must, in a great degree, depend upon the nature of the materials composing the upper surface of the road; but, whatever these may be, the road must be brought to the proper form of section before much improvement can be expected. This should be done by cutting down those parts which are too high, and raising the depressed parts; where, however, the surface of

* Parliamentary Report, 1819, p. 21.

the road is so rotten or brittle that the materials so taken off are not fit to be again used this may be done gradually, and rather by the addition of fresh material to the lowest parts. Unless the materials of which the road has been formed are found to be thus brittle or rotten, or to be already very thin, the course to be pursued is that which is technically termed *lifting* the road, which consists in loosening and turning the surface of the road to a depth of about four inches, and carefully removing such portions of the materials as may be found in an improper state; such as large stones, which should be broken into pieces of the proper dimensions, and then restored to the road. Where, however, the materials of the road are of such a nature that in lifting they would crumble or fall to powder, a different mode of proceeding must be adopted; in this case we must carefully cleanse the surface of the road, from all mud and dirt, after which fresh material, prepared as we have described in the preceding chapter, should be laid on in a very thin coat, *never* exceeding at one time three inches, and, under ordinary circumstances, not more than two inches in thickness. Where the surface of a road, although hard, is found to be very thin, instead of lifting the old materials, it will be requisite to add a fresh coat, preparatory to doing which it would be well just to loosen the surface of the road with a pick, so that the new material may become more rapidly incorporated with the old road.

The best time of the year for repairing roads is in the autumn, when the roads are in a wet state, as the depressed and soft parts of the road are not only then more readily detected, but the surface of the road is then softer, and the new materials are more easily worked into it. As we before observed, the quantity laid on at one time should never exceed three inches in depth, and, generally speaking, a half, or even a third, of this thickness would suffice, if judiciously employed. It is certain that more roads are spoilt from having too much material put upon them than there are from having too little. On this subject Mr. Pen-

fold, whose experience in road-making cannot be questioned, remarks:—"It is one of the greatest mistakes in road-making that can be committed, to lay on thick coats of materials, and when understood, will be no longer resorted to. If there be substance enough already in the road, and which, indeed should always be carefully kept up, it will never be right to put on more than a stone's thickness at a time. A cubic yard, nicely prepared and broken, as before described, to a rod superficial, will be quite enough for a coat, and, if accurately noticed, will be found to last as long as double the quantity put on unprepared and in thick layers. There is no grinding to pieces when so applied; the angles are preserved, and the material is out of sight and incorporated in a very little time. Each stone becomes fixed directly, and keeps its place; thereby escaping the wear and fretting which occur in the other case."*

We have mentioned above, that the most proper time for repairing roads is in the autumn; it must not, however, be supposed that it is *only* at this season that roads require to be repaired; they should, so to speak, be always under repair: every road should be divided into lengths, on each of which an intelligent labourer, who thoroughly understands his business, should be placed, to attend *constantly* and at all times to the proper state of the road, and for which he should be responsible. His office would consist in keeping the road always scraped clean and free from mud, in filling any ruts or hollow places, the moment they appeared, with broken stones, which should be kept in depôts or recesses formed on the sides of the road, and one of which should be provided in each quarter of a mile.† Each man should be provided with a wheelbarrow, a shovel, a pickaxe, and a scraper; each of these, and the other tools and implements requisite for the formation or repair of

* A Practical Treatise on the best Mode of Making and Repairing Roads, p. 15.

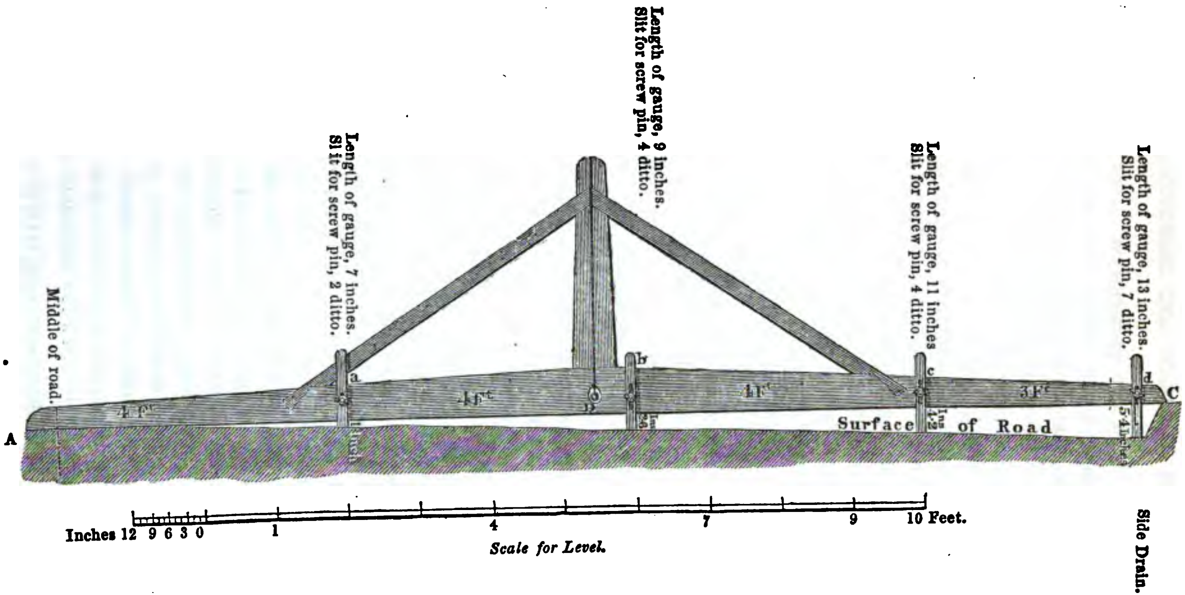
† These Depôts should be capable of containing about 30 cubic yards of material, and are best when the sides are formed with walls, so that the quantity of material in them can be easily ascertained.

roads, will be hereafter described. As the autumn approached, when more had to be done to the road, additional labourers should be engaged to assist; but the constant labourers would be alone responsible for the good order of the road, and the others would act under their direction.

It might be supposed that the system here proposed, of keeping men constantly and permanently to look after the roads, would be attended with great and unnecessary expense; but this opinion will not be held by those who have tried the two methods; it will be found in this, as in most other cases, that the old adage is true, which asserts that "prevention is better than cure;" it is vastly cheaper to prevent a road from getting out of repair, than it is to restore it again to a proper state.

Not only should the mud formed in wet weather be carefully scraped off from its surface to the sides, and removed altogether as soon as it becomes sufficiently solid, but in dry weather the roads should be constantly and regularly watered. In recommending this, we are not considering the comfort of passengers using the road, although that alone would be a sufficient reason, but on account of the road itself. After a long season of drought, the surface of roads becomes, as it were, baked: and in this state, being brittle, would quickly be injured and worn to dust by constant traffic; a regular and moderate supply of water, however, entirely obviates this, and preserves the road in a proper state. Care should, however, be taken that the water is properly applied, as much injury might be done by discharging the water, either in too great quantity, or not evenly distributed; the manner in which the water should be poured upon the road should resemble, as nearly as possible, a gentle shower of rain. The system of watering roads in particular states, even in winter, has been practised with advantage, as the following extract from the evidence of Mr. Benjamin Farey, surveyor of the Whitechapel-road, before the Committee of the House of Commons, will show:—"The wheels stick to the materials, in certain states of the road, in spring and autumn, when it is

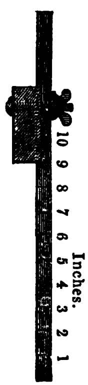
Fig. 13.



Length of gauge, 9 inches.
Slit for screw pin, 4 ditto.
Length of gauge, 7 inches.
Sl it for screw pin, 2 ditto.
Length of gauge, 11 inches
Slit for screw pin, 4 ditto.
Length of gauge, 13 inches.
Slit for screw pin, 7 ditto.
Middle of road.
A
a
b
c
d
C
D
4 Ft
4 Ft
4 Ft
3 Ft
1 Inch
Ins 2·6
Ins 4·2
5·4 Inches
Surface of Road
Inches 12 9 6 3 0
1
4
7
9
10 Feet.
Scale for Level.
Side Drain.

between wet and dry, particularly in heavy foggy weather, and after a frost; by which sticking of the wheels the Whitechapel-road is often, in a short time, dreadfully torn and loosened up; and it is for remedying this evil that I have, for more than eight years past, occasionally watered the road in winter. As soon as the sticking and tearing-up of the materials is observed to have commenced, several water-carts are employed upon these parts of the road, to wet the loamy and glutinous matters so much that they will no longer adhere to the tire of the wheels, and to allow the wheels and feet of the horses to force down and again fasten the gravel-stones; the traffic, in the course of four to twenty hours after watering, forms such a sludge on the surface as can be easily raked off by wooden scrapers, which is performed as quickly as possible; after which, the road is hard and smooth: the advantages of this practice of occasional winter-watering have been great; and it might, I am of opinion, be adopted with like advantages on the other entrances into London, or wherever else the traffic is great, and the gravel-stones are at times observed to be torn up by the sticking of the wheels."*

FIG. 14.

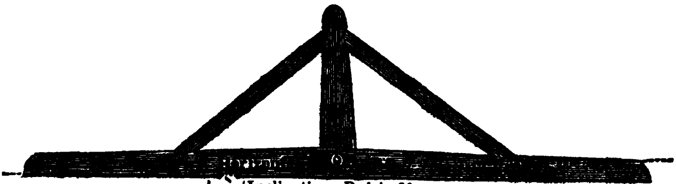


We shall next proceed to a description of the tools or implements employed in the construction and repair of roads. The most important of these is the level used for forming the true transverse section of the road. It is shown in figure 13, and consists of a horizontal straightedge or bar A C, having in the center of its length a plummet B D, for ascertaining when the straightedge is horizontal. Thus far it exactly resembles an ordinary bricklayer's level. A line is drawn near the end A of the bar, and at every four feet from this line a gauge (*a*, *b*, *c*, *d*,) is fixed in a dove-tailed groove, in such a way as to be capable of being moved up or down, so as to adjust the depth of its lower end below the horizontal line of the bottom of the straightedge;

* Parliamentary Report, 1819, p. 40.

and there are thumb screws (one of which is shown on an enlarged scale in figure 14) passing through each gauge, by tightening which the gauge can be fixed when so adjusted. When the bottoms of the gauges *a*, *b*, *c*, and *d*, have been adjusted as shown in fig. 13, they will coincide with the surface recommended to be given to a road 30 feet in width, and such as we have shown in fig. 9; and, in

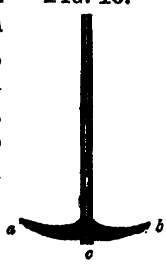
FIG. 15.



Inclination, D 1 in 30.

order to ascertain whether the surface of any existing road is constructed to the proper inclination and form, it is only requisite to apply the level, which, when placed perfectly horizontal, by means of the plummet B D, should rest upon the road at the lower extremity of each of the gauges *a*, *b*, *c*, and *d*. For forming the sides of roads of greater width than 30 feet, it would be convenient to have a level constructed in the manner shown in fig. 15, in which A B is a straightedge about 15 feet long, having in the center of its length a plummet C D, so adjusted that when hanging truly in its place, the lower side of the straightedge should be inclined from a horizontal line at the rate of 1 in 30.

FIG. 16.



The *pick* used for lifting the surface of roads is shown in fig. 16. The bent iron head *a b* should weigh about ten pounds, having a large eye in the center (*c*), in which is fitted the handle, which should be of ash, rather more than two feet in length; one extremity *a* should be formed like the end of a chisel, while the other *b* should terminate in a blunt point. Both ends should be tipped with steel.

FIG. 17.

The most useful form of *shovel* for road purposes is shown in fig. 17. The blade should be somewhat pointed, and the handle bent, so as to enable the person using it to bring the blade flat upon the surface of the road without excessive stooping.

The ordinary *wheelbarrows* are of ash or elm, with cast-iron wheels; but it would be an advantage if wheelbarrows for road purposes were made of wrought iron, which would combine strength and durability with lightness. Of whatever material, however, they are constructed, they should not exceed nine inches in depth, and their sides should be splayed with a slope of 2 to 1. It would be also very desirable to have hooks placed on their sides to receive a shovel and pick.

The *screens*, or *sieves*, employed for separating the coarse gravel from the hoggin or small gravel, consist of iron wires or slender rods, placed at equal distances apart, and fixed in a frame of wood, the sides of which are raised about five inches above the plane of the wires. In the screens the frames are rectangular, about 5 feet 6 inches in height and 3 feet wide, and the wires are stretched in the direction of its length at distances varying from half an inch to an inch and a quarter, according to the size of the stone required; and these wires are kept in place by others crossing them at intervals of five or six inches. When used, they are placed so that the plane of the wires is inclined about 30° from the upright, and the gravel to be screened being dashed or thrown forcibly against them, the finer particles pass through and fall on the further side of the screen, while the large stones roll down its surface and fall on the nearest side. The sieves are somewhat different in form, the frame being circular, forming a cylinder about 6 inches in depth and 20 inches in diameter, the wires being placed either as we have already

Fig. 18.

Iron 2 lbs.
Length, 6¾ inches.

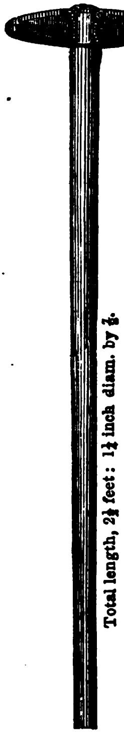


Fig. 19.

Iron 1 lb.
Length, 5¾ inches.

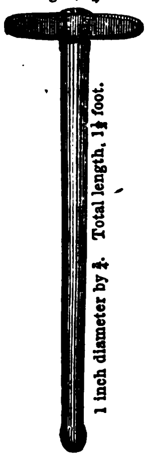
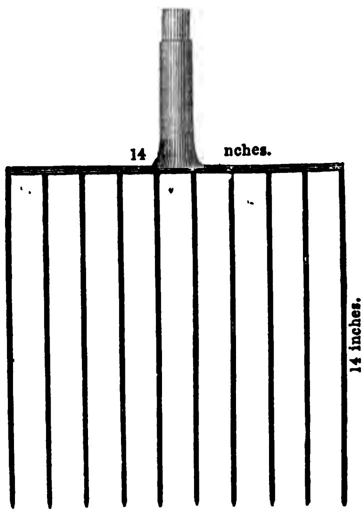


Fig. 20.

Fig. 21.



described or equally close in both directions, and forming a kind of bottom to the cylinder. The sieve is held horizontally by one man, while the other throws into it a shovelful of gravel; upon shaking the sieve the fine hoggin falls through, leaving the stones in the sieve, which are then thrown by the man into anything which may be placed to receive them. The latter is generally the best and cheapest mode of screening gravel.

The *hammers* generally employed for breaking stones are of two sizes, and are shown in figs. 18 and 19. The handles should be of straight-grained ash, and the iron heads of the weight and form shown in the drawings; the faces should be spherical, and case-hardened or steeled.

Fig. 20 represents the ring to be used for testing the size of the broken stones. Its internal diameter is $2\frac{1}{2}$ inches, and the largest stones should be able to be passed through the ring in every direction.

Fig. 21 represents a *pronged fork*, to be used instead of a shovel for taking up the stones to throw upon the road. The advantages attending its use are, that a man can take up the stones much quicker and easier than with a shovel, and free from all dirt and extraneous matter, which, in the case of broken angular stones, is of importance.

It is sometimes advantageous to roll the surface of new roads, in order to consolidate the material, and for this purpose a cast-iron roller is usually employed, about five feet wide, four feet in diameter, and weighing about four tons.

The *rakes*, which should be employed in filling in ruts and hollow places in the surface of roads, should be formed with prongs between 2 and 3 inches in length, fixed at the distance of three-quarters of an inch apart, into a wooden head about 11 inches in length. Their handles should be formed of ash, and should be about six feet in length.

Scrapers are indispensable for preserving roads in a proper state and free from mud. They are usually constructed of wood shod with wrought iron, but it is much better to make them entirely of iron. They should be 6 inches in depth, and about 18 inches in length, and slightly

curved at each extremity to prevent the escape of mud at each side.

Scraping Machines have been invented, and are very generally employed, by means of which the surface of a road may be scraped much more regularly and quickly than with the old scrapers. They consist of a number of iron scrapers, attached to a frame mounted on wheels, which are so placed that, when the body of the machine is raised somewhat, the wheels are lifted from the ground, and the whole weight of the machine is thrown upon the scrapers, which, upon the machine being drawn across the road, scrape all the mud from its surface, and carry it to the sides.

A machine has also been invented by Mr. Whitworth, of Manchester, which has been extensively employed both at that place and in London, for sweeping up the mud from the roads and carrying it away at once. It consists of a species of endless broom, passing round rollers attached to a mud cart, and so connected by cogged wheels with the wheels of the cart that, when the latter is drawn forwards, the broom is caused to revolve, and sweeps the mud from the surface of the road up an inclined plane into the cart. The machine is drawn by one horse; and by its aid the roads are swept much more rapidly and better than by the old system of scraping, and with far less injury to the surface of the road and annoyance to the passengers.

CHAPTER V.

ON HEDGES AND FENCES.

In most situations fences of some description are required to mark the boundaries of roads, and separate them from the adjoining lands. They should, however, always be dispensed with wherever it is possible to do so,

for the reason, that all fences, of whatever kind, to a greater or less extent deprive the surface of the road of a free exposure to the action of the wind and sunshine, both of which are essential to maintain it in a dry state. Few persons are aware of the extent to which a road may be injured by being fenced in with high hedges, or lined with trees; the latter are worse even than hedges, because they not only shelter the road from the effects of the air and sun, but further injure it by the drippings of rain which fall from their leaves, and retain the road in a wet state long after it would otherwise have become dry.

Where fences are indispensable, they should therefore be kept as low as possible, and thrown as far as they can be from the sides of the road. When the road has a deep ditch on either side, it then becomes necessary, to prevent accidents, that the fence should be placed between the road and the ditch; but in all other situations the fence should be placed on the field side of the ditch; for the double reason, that in so doing the surface drainage of the road into the side ditches is less interfered with, and that the road is then not so much sheltered by the fence itself.

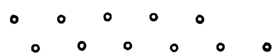
The different descriptions of fence which may be employed are very various; in districts where stone is plentiful, and especially in the immediate neighbourhood of the quarries, where stone rubble can be obtained at a trifling cost, dry walls built of this description of stone, without any mortar, are very good and cheap, and when once built require little or no repairing.

As far as the road itself is concerned, an open post-and-rail fence is the best which can be employed, because it scarcely impedes the action of the wind and sun upon the surface of the road; but the great practical objection to a timber fence of any description is, its liability to decay, which occasions a frequent and constant expense to be incurred in its renewal.

The most general, and, all things considered, the most useful, fence is the quickset hedge: and, if properly planted, and carefully attended to for the first few years, a natural

fence may thus be obtained, sufficiently strong to resist the efforts of every description of cattle to get through it, and to maintain which but a very small annual sum will be requisite. A bank or mound of earth, at least two feet in depth, should be prepared for the reception of the quicks, which should be three-years plants which have been transplanted two years. The best description of soil is one of a light sandy nature, which will admit sufficient moisture to nourish the plants, aud retain a portion even in dry seasons. Heavy clay soils are not sufficiently pervious to water, and plants placed in such soils are never found to thrive. A mixture of peat or rotten leaves is of great use, and causes the plants to grow with much vigour. The most usual way is, to plant the quicks in a single row, at distances of about four inches apart. But a much better hedge is formed by planting them in a double row, as shown in fig. 22, with a space of six inches between the two rows, and the plants the same distance apart in each

FIG. 22.



row, and so arranged that the plants in one row are opposite the spaces in the other. By this arrangement, although the plants are really not so crowded, but have more space round their roots from which to derive nourishment, they form a thicker hedge. The proper time for planting quicks is either during the autumn or spring, and in fine seasons the operation may be continued during the whole winter. A temporary fence should be put up to protect the young plants from injury, or from having the shoots eaten off by cattle; and this fence should be kept up until the hedge has attained sufficient strength to require its protection no longer, which, under favourable circumstances, will be in about three or four years after the quicks have been planted. In order that the plants should thrive, they must be very carefully attended to at

first, and it is essential that they should be properly cleaned and weeded at least twice every year; and once every year, towards the conclusion of the summer, the hedge should be judiciously trimmed, not to such an extent as to produce stunted plants, but merely cutting off the upper and more straggling shoots, so as to bring it to a level and even surface: by proceeding in this manner, in about three years after planting, a neat, strong, and compact hedge of healthy plants will be obtained.

When the hedge or fence is placed between the road and the side ditches, it is essential that small drains be formed at least every fifteen yards, to convey the water from the side tables or gutters through the fence into the ditches.

CHAPTER VI.

ON PAVED ROADS AND STREETS.

In constructing roads, or rather streets, through towns or cities, where the amount of traffic is considerable it will be found desirable to pave their surface. The advantages belonging to pavements in such situations over macadamised roads are considerable; where the latter are exposed to an incessant and heavy traffic, their surface becomes rapidly worn, rendering constant repairs requisite, which are not only attended with very heavy expense, but also render the road very unpleasant for being travelled upon while being done; they also require much more attention in the way of scraping or sweeping, and in raking-in ruts. And some difficulty would be experienced in towns to find places in which the materials, which would be constantly wanted for repairing the road, could be deposited. In dry weather the macadamised road would always be dusty, and in wet weather it would be covered with mud. The only advantage which such a road really possesses over a pavement is, the less noise produced by carriages in passing over it; but

this advantage is very small when the pavement is properly laid.

In laying pavements, as in forming roads, the first and one of the most important objects should be, to obtain a firm and unyielding foundation. It should be borne in mind, that the pavement itself, whatever may be its thickness, and however carefully and closely the stones of which it is composed may be fitted together, must be entirely inadequate to support the heavy load to which all roads are occasionally exposed; and unless the foundation beneath the pavement is sufficiently firm to support these loads itself, the pavement will subside, and its surface soon become uneven. The real object of paving is nothing more than to give to the road a hard surface, not so liable to wear as it would itself be.

Several different methods have been employed of forming the foundations of pavements, such as concrete and broken stone; but where it can be done, it is perhaps best to lay the new pavement on the old surface of the road, whether paved or macadamised, taking care of course that its surface has been brought first to an even state, and of the required form of cross section.

The practice of laying the new pavement on the top of the old has been a great deal used in Paris, and has there been found to answer extremely well. It is usual to take up and relay the old pavement, in order that its surface may be even and true, after which it is just covered with gravel, on which the new stones are bedded. Mr. Telford strongly recommended the surface upon which the pavement was intended to be laid to be prepared as though intended for a macadamised road, and, in that state, that it should be used by carriages until it had become thoroughly consolidated, when the pavement should be laid on the top of the hard road so formed, the stones being properly bedded in a kind of coarse mortar; and Mr. Edgeworth, in his work on roads, states that this method of forming paved roads had been extensively employed in Dublin, and had been found to be attended with considerable success.

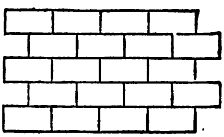
In cases, however, in which it would not be practicable to lay the new pavement upon the surface of the existing road, the following method should be employed for forming a good foundation. The loose ground at the surface should first be entirely removed; the depth to which it may be requisite to do this must depend upon the nature of the ground itself; unless the ground be very solid, it should be removed to such a depth as will allow of 18 inches of concrete being put in beneath the pavement. In some situations so great a thickness as this may not be requisite, but it is much better, and in the "long run" much *cheaper*, to err rather in forming too strong a foundation, than one the failure of which necessitates the taking up and relaying of the pavement. As soon as the loose ground has been removed, a layer of concrete, prepared in the manner already described at page 96, should be evenly spread over the whole area of the intended road: its depth, as before remarked, must depend on the nature of the subsoil, and the extent of traffic to which the road will be exposed; it should never, however, be less than 12 inches, and, under ordinary circumstances, not less than 18 inches. Its upper surface should be formed to the true form of cross section intended to be given to the road, which should under no circumstances be greater than that already recommended at page 86 to be given to the surface of common roads, and in most cases a less inclination would be found sufficient and preferable.

The stones should be well bedded upon the concrete in a kind of coarse mortar, which should also be well filled in between their joints.

With regard to the stone to be employed for this purpose, several of the harder kinds are used, such as granite, whinstone, limestone, and freestone; of these two last, however, only the very hardest varieties should be used. Of all materials granite is the best, and more particularly those kinds, such as the Guernsey and Aberdeen, which do not wear smooth and acquire a polished surface, which is a great practical defect attending the employment of exces-

sively hard stone. With regard to the form of the stones, experience has shown that the best is that of rectangular blocks, from 8 to 15 inches in depth (depending on the amount and nature of the traffic), about 18 inches in length, and not more than 3 or 4 inches in width. Until lately it was considered better to have stones of much greater width, under the supposition that having a larger base they would be better able to support the superincumbent weight, but experience has shown that the narrow stones are by far the best. Great care should be taken in sorting the stones according both to their depths and widths: for if the stones are of unequal depth, and the surface of the concrete has been made, as it should be, even and parallel to the intended surface of the road, any stones less than the general depth would require more mortar to be placed under them, and would consequently settle down more than the others, and form hollows on the surface of the road. They should also be sorted according to their width, so that they may run entirely across the street in parallel courses, as shown in fig. 23, and the stones in each course should be so selected as to break joint with those in each adjoining course, as there shown.

FIG. 23.

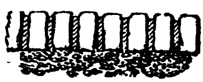


It is essential to the formation of a good pavement that a firm and substantial curb should be well laid on each side of the road, for it to abut against; and in laying the pavement the courses should be commenced at each side, and worked towards the center; the joints between the stones should be as thin as possible, and the last stone should fit tightly, so as to form a kind of key to the whole. After the stones have been set they should be well rammed down with a heavy punner, and any stone which went down below the general level should be taken up, and packed underneath. It is not usual to go to the expense of bedding the stones in mortar in the manner here recommended, but only to pour a thin grouting of sand and lime over the

surface, after the pavement has been laid, which finds its way, although very imperfectly, into the interstices between the stones. It is, however, a mistaken economy, as a pavement laid as here described upon a firm concrete foundation, and having the joints perfectly formed with good mortar, would last almost for ever, since nothing less than the positive wearing away and destruction of the stone would render its renewal necessary.

Some little attention is necessary to be given to paved roads for a few months after being opened for traffic, in order to prevent irregular settlement in the stones, and consequently an uneven and irregular surface. The moment any portion of the road is found to settle below the general level it should be taken up, and a sufficient quantity of fine concrete put underneath it to bring it again *slightly* above the level of the remainder. Great attention should also be paid to the manner in which the pavement is re-laid after being disturbed for the repair of sewers or water and gas pipes; the excavated ground, when thrown back, should be well punned, or beaten down in layers of not more than a foot in thickness, and at least 18 inches of concrete should be laid on the top, under the pavement; the surface of this concrete should be about an inch above the general level, and the stones should be properly bedded in the manner already described, care being taken that the stones correspond in depth and width with those already in place on either side, and furthermore that the last stone, in making good each course, fits tightly into its place.

FIG. 24.



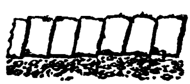


FIG. 25.

In laying pavement in streets having a considerable inclination, two methods have been employed to afford a more sure and perfect hold for the horses' feet than the ordinary pavement. The first method is shown in fig. 24, and consists in laying between each row of paving-stones a course of slate, rather less than an inch in thickness, and to about the same extent less in depth than the stones themselves. By this means

a series of small channels or grooves, about an inch in width and depth, are formed between each row of stones, which afford sufficient stay for the horses' feet; this method has been adopted in Tooley-street, Southwark. The other method is somewhat simpler, and consists in merely placing the ordinary paving-stones somewhat canted on their beds, as shown in fig. 25, so as to form a series of ledges or steps, against which the horses' feet being planted, a secure footing is obtained.

Of late years wood has been introduced as a material for paving streets, and has been rather extensively employed both in Russia and America. It has been tried in various parts of London, and generally with small success, the cause of its failure being identical with the cause of the enormous sums being spent annually in the repairs of the streets generally, namely, the want of a proper foundation; a want which was sooner felt with wood than with granite, in consequence of the less weight and inertia of the wood. The comfort resulting from the use of wooden pavement, both to those who travelled, and those who lived in the streets, from the diminished jolting and noise, was so great, that it is just matter of surprise that so little care was taken in forming that which a very little consideration would have shown to be indispensable to its success, namely, a good foundation. Slipperiness of its surface, in particular states of the weather, was also found to be a disadvantage belonging to wooden pavement, but means might be devised which would render its surface at all times safe, and afford a secure footing for horses. As regards durability, it has scarcely been used for a sufficient period to allow a comparison being made with other materials, but from the result of some observations communicated by Mr. Hope to the Scottish Society of Arts, which are given by Mr. Leahy in a note at page 76 of his work on roads, it appears that wooden blocks when placed with the end of the grain exposed, wear *less than granite*. At first sight this result might appear questionable, but it is a well-ascertained fact that, where wood and iron move in

contact in machinery, the iron generally wears more rapidly than the wood, the reason appearing to be, that the surface of the wood soon becomes covered with particles of dust and grit, which become partially embedded in it, and, while they serve to protect the wood, convert its surface into a species of file, which rapidly wears away whatever it rubs against.

CHAPTER VII.

ON TAKING OUT QUANTITIES FOR ESTIMATES.

The operation of making out an estimate for any description of engineering work may be divided into two distinct parts: namely, in the first place, calculating the actual quantity of each description of work to be executed; and, in the second place, affixing to these quantities just and reasonable prices, such as the work might really be executed for.

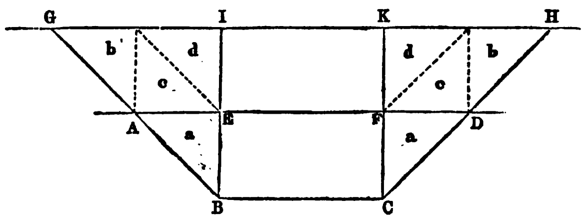
It is only upon the first of these, namely, taking out the quantities, that we propose to speak here; not that the other is the less important, but because it would be difficult to lay down any principles for priceing work, or to fix any standard prices, without the probability of leading to erroneous results. The cost of different descriptions of work depends upon so many varying circumstances, and is affected so greatly by the nature of the locality, that it would be impossible to give any standard prices. The surest method to obtain correct information on this matter is, by inquiries as to the usual cost of such work in the particular locality itself.

In the construction of roads, the principal item of expense is the earthwork, or the cost of forming the cuttings and embankments to obtain the required levels for the formation surface, in excavating the ditches and forming

the banks, and in laying on the metalling or ballast to form the road. Of all these different descriptions of work, the first; namely, the cuttings and embankments, are the only ones the estimation of the quantity of which is attended with any difficulty. The others, being generally constant, are readily obtained by ascertaining the quantity in a given length, as a yard, and then multiplying that quantity by the total length of the road.

In estimating the cubic content of any cutting or embankment, the operation will be simplified by considering the slopes apart from the trunk or main body of the cutting. For example, let fig. 26 be the section of a cutting,

FIG. 26.



A D being the natural surface of the ground; then if B C is the width of the formation surface, B C F E will be the trunk or central portion of the cutting, and A E B, F C D, will be the side slopes. Now the width of the first is constant, being the formation width, while its depth varies as the depth of the cutting; and therefore its cubic content for a given length forward is directly proportional to the depth of the cutting. If, for instance, the line G H were the natural surface of the ground instead of A D, the cutting being now twice as deep as before, the cubic content of the trunk I B C K would be twice as great as that of E B C F. The cubic content, however, of the slopes increases in the proportion of the square of the depth of the cutting, as is evident from the figure, in which I B being *twice* as great as E B, the slope G I B is *four* times as great as A E B, the triangles *a*, *b*, *c*, and *d* being evidently equal. It is in consequence of these two quantities varying in a different pro-

portion that it is found convenient to estimate them separately. In order to facilitate the calculation of earthwork, several tables have been published, the most complete and elaborate of which are those by Sir John Macneill. The following table will be found very useful in estimating the content of cuttings or embankments of moderate depth, and will give the result very nearly true, except in cases in which the two ends of the cutting are of very different depths. The first, fourth, and seventh columns contain the depth of the cutting or height of embankment, in feet, for every tenth of a foot, from 0·1 to 25·2 feet; the second, fifth, and eighth columns express the content, in cubic yards, of one foot in width, and one chain in length, of a portion of the trunk or central part of a cutting, whose mean depth is shown in the preceding column. The quantities taken from these columns must be multiplied by the formation width. The third, sixth, and ninth columns express the content in cubic yards of a length of one chain of both slopes, when the slopes are formed at 1 to 1. With any other ratio the quantities derived from these columns must be increased in the same proportion. Thus, if the slopes are 3 to 1, the quantity obtained from the table must be multiplied by 3.

Height or depth.	Content for a length of one chain. Of each foot in width of trunk.	Of slopes taken at 1 to 1.	Height or depth.	Content for a length of one chain. Of each foot in width of trunk.	Of slopes taken at 1 to 1.	Height or depth.	Content for a length of one chain. Of each foot in width of trunk.	Of slopes taken at 1 to 1.
Feet.	Cub. yds.	Cub. yds.	Feet.	Cub. yds.	Cub. yds.	Feet.	Cub. yds.	Cub. yds.
0·1	·24	·02	4·3	10·51	45·20	8·5	20·78	176·6
0·2	·49	·10	4·4	10·76	47·32	8·6	21·02	180·8
0·3	·73	·22	4·5	11·00	49·50	8·7	21·27	185·0
0·4	·99	·39	4·6	11·24	51·72	8·8	21·50	189·3
0·5	1·22	·61	4·7	11·49	54·10	8·9	21·76	193·6
0·6	1·47	·88	4·8	11·73	56·42	9·0	22·00	198·0
0·7	1·71	1·20	4·9	11·98	58·79	9·1	22·24	202·4
0·8	1·96	1·56	5·0	12·22	61·11	9·2	22·49	206·9
0·9	2·20	1·98	5·1	12·47	63·58	9·3	22·73	211·4
1·0	2·44	2·44	5·2	12·71	66·10	9·4	22·98	216·0
1·1	2·69	2·96	5·3	12·96	68·66	9·5	23·22	220·6
1·2	2·93	3·52	5·4	13·20	71·28	9·6	23·47	225·3
1·3	3·18	4·13	5·5	13·44	73·94	9·7	23·71	230·0
1·4	3·42	4·79	5·6	13·69	76·66	9·8	23·96	234·8
1·5	3·67	5·50	5·7	13·93	79·42	9·9	24·20	239·6
1·6	3·91	6·26	5·8	14·18	82·23	10·0	24·44	244·4
1·7	4·16	7·06	5·9	14·42	85·09	10·1	24·69	249·4
1·8	4·40	7·92	6·0	14·67	88·00	10·2	24·93	254·3
1·9	4·64	8·82	6·1	14·91	90·96	10·3	25·18	259·3
2·0	4·89	9·78	6·2	15·16	93·96	10·4	25·42	264·4
2·1	5·13	10·78	6·3	15·40	97·02	10·5	25·67	269·5
2·2	5·38	11·83	6·4	15·64	100·1	10·6	25·91	274·6
2·3	5·62	12·93	6·5	15·89	103·3	10·7	26·16	279·9
2·4	5·87	14·08	6·6	16·13	106·5	10·8	26·40	285·1
2·5	6·11	15·28	6·7	16·38	109·7	10·9	26·64	290·4
2·6	6·36	16·52	6·8	16·62	113·0	11·0	26·89	295·8
2·7	6·60	17·82	6·9	16·87	116·4	11·1	27·13	301·2
2·8	6·84	19·16	7·0	17·11	119·8	11·2	27·38	306·6
2·9	7·09	20·56	7·1	17·36	123·2	11·3	27·62	312·1
3·0	7·33	22·00	7·2	17·60	126·7	11·4	27·87	317·7
3·1	7·58	23·49	7·3	17·84	130·3	11·5	28·11	323·3
3·2	7·82	25·03	7·4	18·09	133·8	11·6	28·36	328·9
3·3	8·07	26·62	7·5	18·33	137·5	11·7	28·60	334·6
3·4	8·31	28·26	7·6	18·58	141·2	11·8	28·84	340·4
3·5	8·56	29·94	7·7	18·82	144·9	11·9	29·09	346·2
3·6	8·80	31·68	7·8	19·07	148·7	12·0	29·33	352·0
3·7	9·04	33·46	7·9	19·30	152·6	12·1	29·58	357·9
3·8	9·29	35·30	8·0	19·56	156·4	12·2	29·82	363·8
3·9	9·53	37·18	8·1	19·80	160·4	12·3	30·07	369·8
4·0	9·78	39·11	8·2	20·04	164·4	12·4	30·31	375·9
4·1	10·02	41·09	8·3	20·29	168·4	12·5	30·56	381·9
4·2	10·27	43·12	8·4	20·53	172·5	12·6	30·80	388·1

Height or depth.	Content for a length of one chain. Of each foot in width of trunk.	Content for a length of one chain. Of slopes taken at 1 to 1.	Height or depth.	Content for a length of one chain. Of each foot in width of trunk.	Content for a length of one chain. Of slopes taken at 1 to 1.	Height or depth.	Content for a length of one chain. Of each foot in width of trunk.	Content for a length of one chain. Of slopes taken at 1 to 1.
Feet.	Cub. yds.	Cub. yds.	Feet.	Cub. yds.	Cub. yds.	Feet.	Cub. yds.	Cub. yds.
12·7	31·04	394·3	16·9	41·31	698·2	21·1	51·58	1088
12·8	31·29	400·5	17·0	41·56	706·4	21·2	51·82	1099
12·9	31·53	406·8	17·1	41·80	714·8	21·3	52·07	1109
13·0	31·78	413·1	17·2	42·04	723·2	21·4	52·31	1119
13·1	32·02	419·5	17·3	42·29	731·6	21·5	52·56	1130
13·2	32·27	425·9	17·4	42·53	740·1	21·6	52·80	1140
13·3	32·51	432·4	17·5	42·78	748·6	21·7	53·04	1151
13·4	32·76	438·9	17·6	43·02	757·2	21·8	53·29	1162
13·5	33·00	445·5	17·7	43·27	765·8	21·9	53·53	1172
13·6	33·24	452·1	17·8	43·51	774·5	22·0	53·78	1183
13·7	33·49	458·8	17·9	43·76	783·2	22·1	54·02	1194
13·8	33·73	465·5	18·0	44·00	792·0	22·2	54·27	1205
13·9	33·98	472·3	18·1	44·24	800·8	22·3	54·51	1216
14·0	34·22	479·1	18·2	44·49	809·7	22·4	54·76	1227
14·1	34·47	486·0	18·3	44·73	818·6	22·5	55·00	1238
14·2	34·71	492·9	18·4	44·98	827·6	22·6	55·24	1249
14·3	34·96	499·9	18·5	45·22	836·6	22·7	55·49	1260
14·4	35·20	506·9	18·6	45·47	845·7	22·8	55·73	1271
14·5	35·44	513·9	18·7	45·71	854·8	22·9	55·98	1282
14·6	35·69	521·1	18·8	45·96	864·0	23·0	56·22	1293
14·7	35·93	528·2	18·9	46·20	873·2	23·1	56·47	1305
14·8	36·18	535·4	19·0	46·44	882·4	23·2	56·71	1316
14·9	36·42	542·7	19·1	46·69	891·8	23·3	56·96	1327
15·0	36·67	550·0	19·2	46·93	901·1	23·4	57·20	1339
15·1	36·91	557·4	19·3	47·18	910·5	23·5	57·44	1350
15·2	37·16	564·8	19·4	47·42	920·0	23·6	57·69	1362
15·3	37·40	572·2	19·5	47·67	929·5	23·7	57·93	1373
15·4	37·64	579·7	19·6	47·91	939·1	23·8	58·18	1385
15·5	37·89	587·3	19·7	48·16	948·7	23·9	58·42	1397
15·6	38·13	594·9	19·8	48·40	958·3	24·0	58·67	1408
15·7	38·38	602·5	19·9	48·64	968·0	24·1	58·91	1420
15·8	38·62	610·2	20·0	48·89	977·8	24·2	59·16	1432
15·9	38·87	618·0	20·1	49·13	987·6	24·3	59·40	1443
16·0	39·11	625·8	20·2	49·38	997·4	24·4	59·64	1455
16·1	39·36	633·6	20·3	49·62	1007	24·5	59·89	1467
16·2	39·60	641·5	20·4	49·87	1017	24·6	60·13	1479
16·3	39·84	649·5	20·5	50·11	1027	24·7	60·38	1491
16·4	40·09	657·5	20·6	50·36	1037	24·8	60·62	1503
16·5	40·33	665·5	20·7	50·60	1047	24·9	60·87	1516
16·6	40·58	673·6	20·8	50·84	1058	25·0	61·11	1527
16·7	40·82	681·7	20·9	51·09	1068	25·1	61·36	1540
16·8	41·07	689·9	21·0	51·33	1078	25·2	61·60	1552

As an example of the use of this table, we shall proceed to estimate the quantities in the cutting and embankment shown on the working section, fig. 8. In the following table, the first column contains the number of the peg, the second the depth of cutting or height of embankment, the third the cubic content of the corresponding portion of the trunk, and the fourth column the content of the slopes.

CUTTING No. 1.

No. of peg.	Depth of cutting.	Trunk.	Slopes.
1	·0	·37	·11
2	·6	1·47	·88
3	·9	2·20	1·98
4	1·2	2·93	3·52
5	1·6	3·91	6·26
6	1·9	4·64	8·82
7	2·0	4·89	9·78
8	1·9	4·64	8·82
9	1·9	4·64	8·82
10	2·1	5·13	10·78
11	2·2	5·38	11·83
12	2·4	5·87	14·08
13	2·3	5·62	12·93
14	2·3	5·62	12·93
15	2·5	6·11	15·28
16	2·1	5·13	10·78
17	2·3	5·62	12·93
18	2·5	6·11	15·28
19	2·2	5·38	11·83
20	1·6	3·91	6·26
21	·8	1·96	1·56
		91·53	185·46
		40	
		3661·20	
		185·46	
		3846·66 cub. yds.	

EMBANKMENT No. 1.

No. of peg.	Height of embankment.	Trunk.	Slopes.
22	·6	1·47	·88
23	2·2	5·38	11·83
24	3·5	8·56	29·94
25	4·0	9·78	39·11
26	3·8	9·29	35·30
27	2·6	6·36	16·52
28	1·3	3·18	4·13
29	·3	·73	·22
		44·75	137·93
		40	
		1790·00	
		137·93	
		68·96	
		1996·89 cub. yds.	

It will be remarked that, at peg 1, where the cutting has no depth, we have yet inserted quantities in the third and

fourth columns. The manner in which these were derived is as follows. Although at the peg itself there is no cutting, at the next peg the depth is 0·6, and therefore the *mean depth* is 0·3, which, in the table, gives 0·73 and 0·22. As, however, we have here only half a chain (as it is the commencement of the section), we insert half these quantities, or 0·37 and 0·11. The sum of all the separate portions of the trunk, being obtained by addition, is then multiplied by 40, the width of the formation, to which the sum of the slopes being added, gives 3846·66 cubic yards as the content of the cutting. In the case of the embankment, the slopes being 1½ to 1, we add *one and a half* times the sum of the slopes, and thus obtain 1996·89 cubic yards as its content. By reference to the working section, fig. 8, it will be seen that the quantities there given agree with the above.

CHAPTER VIII.

PROFESSOR MAHAN'S ELEMENTARY ESSAY ON ROAD-MAKING.

IN establishing a line of internal communication of any character, whether it be an ordinary road, railroad, or canal, the main considerations to which the attention of the engineer must be directed in the outset are—1, the probable character and amount of traffic over the line; 2, the wants of the community in the neighbourhood of the line; 3, the natural features of the country, between the points of *arrival* and *departure*, as regards their adaptation to the proposed communication.

As the last point alone comes exclusively within the province of the engineer's art, and within the limits prescribed to this work, attention will be confined solely to its consideration.

Reconnaissance.—A thorough examination and study of the ground by the eye, termed a *reconnaissance*, is an indispensable preliminary to any more accurate and minute

survey by instruments, to avoid loss of time, as by this more rapid operation any ground unsuitable for the proposed line will be as certainly detected by a person of some experience, as it could be by the slow process of an instrumental survey. Before, however, proceeding to make a *reconnaissance*, a careful inspection of the general maps of that portion of the country through which the communication is to pass, will facilitate, and may considerably abridge, the labours of the engineer; as from the natural features laid down upon them, particularly the direction of the water-courses, he will at once be able to detect those points which will be favourable, or otherwise, to the general direction selected for the line. This will be sufficiently evident when it is considered—1, that the water-courses are necessarily the lowest lines of the valleys through which they flow, and that their direction must also be that of the lines of greatest declivity of their respective valleys; 2, that from the position of the water-courses the position also of the high grounds by which they are separated naturally follows, as well as the approximate position at least of the ridges, or highest lines of the high grounds, which separate their opposite slopes, and which are at the same time the lines of greatest declivity common to these slopes, as the water-courses are the corresponding lines of the slopes that form the valleys.

Keeping these facts (which are susceptible of rigid mathematical demonstration) in view, it will be practicable, from a careful examination of an ordinary general map, if accurately constructed, not only to trace, with considerable accuracy, the general direction of the ridges from having that of the water-courses, but also to detect those depressions in them which will be favourable to the passage of a communication intended to connect two main or two secondary valleys. The following illustrations may serve to place this subject in a clearer aspect.

If, for example, it be found that on any portion of a map the water-courses seem to diverge from or converge towards one point, it will be evident that the ground in the first case must be the common source or supply of the water-courses, and therefore the highest; and, in the second case, that it is the lowest, and forms their common recipient.

If two water-courses flow in opposite directions from a common point, it will show that this is the point from which they derive their common supply, at the head of

their respective valleys, and that it must be fed by the slopes of high grounds above this point; or, in other words, that the valleys of the two water-courses are separated by a chain of high grounds, which, at the point where it crosses them, presents a depression in its ridge, which would be the natural position for a communication connecting the two valleys.

If two water-courses flow in the same direction and parallel to each other, it will simply indicate a general inclination of the ridge between them, in the same direction as that of the water-courses. The ridge, however, may present in its course elevations and depressions, which will be indicated by the points in which the water-courses of the secondary valleys, on each side of it, intersect each other on it; and these will be the lowest points at which lines of communication, through the secondary valleys, connecting the main water-courses, would cross the dividing ridge.

If two water-courses flow in the same direction, and parallel to each other, and then at a certain point assume divergent directions, it will indicate that this is the lowest point of the ridge between them.

If two water-courses flow in parallel but opposite directions, depressions in the ridge between them will be shown by the meeting of the water-courses of the secondary valleys on the ridge; or by an approach towards each other, at any point, of the two principal water-courses.

Furnished with the data obtained from the maps, the character of the ground should be carefully studied both ways by the engineer, first from the point of departure to that of arrival, and then returning from the latter to the former, as without this double traverse natural features of essential importance might escape the eye.

Surveys.—From the results of the *reconnaissance*, the engineer will be able to direct understandingly the requisite surveys, which consist in measuring the lengths, determining the directions, and ascertaining both the longitudinal and cross levels of the different routes, or, as they are termed, *trial lines*, with sufficient accuracy to enable him to make a comparative estimate both of their practicability and cost. As the expense of making the requisite surveys is usually but a small item compared with that of constructing the communication, no labour should be spared in running every practicable line, as otherwise natural

features might be overlooked which might have an important influence on the cost of construction.

Map and Memoir.—The results of the surveys are accurately embodied in a map exhibiting minutely the topographical features and sections of the different trial lines, and in a memoir which should contain a particular description of those features of the ground that cannot be shown on a map, with all such information on other points that may be regarded as favourable, or otherwise, to the proposed communication; as, for example, the nature of the soil, that of the water-courses met with, &c., &c.

Location of Common Roads.—In selecting among the different trial lines of the survey the one most suitable to a common road, the engineer is less restricted, from the nature of the conveyance used, than in any other kind of communication. The main points to which his attention should be confined are—1, to connect the points of arrival and departure by the most direct, or shortest line; 2, to avoid unnecessary ascents and descents, or, in other words, to reduce the ascents and descents to the smallest practicable limit; 3, to adopt such suitable slopes, or *gradients*, for the *axis*, or centre line of the road, as the nature of the conveyance may demand; 4, to give the axis such a position, with regard to the surface of the ground and the natural obstacles to be overcome, that the cost of construction for the excavations and embankments required by the gradients, and for the bridges and other accessories, shall be reduced to the lowest amount.

Deviations from the right line drawn on the map, between the points of arrival and departure, will be often demanded by the natural features of the ground. In passing the dividing ridges of main, or secondary valleys, for example, it will frequently be found more advantageous, both for the most suitable gradients, and to diminish the amount of excavation and embankment, to cross the ridge at a lower point than the one in which it is intersected by the right line, deviating from the right line either towards the *head*, or upper part of the valley, or towards its outlet, according to the advantages presented by the natural features of the ground, both for reducing the gradients and the amount of excavation and embankment.

Where the right line intersects either a marsh or water-course, it may be found less expensive to change the direc-

tion, avoiding the marsh, or intersecting the water-course at a point where the cost of construction of a bridge, or of the approaches to it, will be more favourable than the one in which it is intersected by the right line.

Changes from the direction of the right line may also be favourable for the purpose of avoiding the intersection of secondary water-courses; of gaining a better soil for the roadway; of giving a better exposure of its surface to the sun and wind; or of procuring better materials for the road-covering.

By a careful comparison of the advantages presented by these different features, the engineer will be enabled to decide how far the general direction of the right line may be departed from with advantage to the location. By choosing a more sinuous course the length of the line will often not be increased to any very considerable degree, while the cost of construction may be greatly reduced, either in obtaining more favourable gradients, or in lessening the amount of excavation and embankment.

When the points of arrival and departure are upon different levels, as is usually the case, it will seldom be practicable to connect them by a continual ascent. The most that can be done will be to cross the dividing ridges at their lowest points, and to avoid, as far as practicable, the intersection of considerable secondary valleys which might require any considerable ascent on one side and descent on the other.

The gradients upon common roads will depend upon the kind of material used for the road-covering, and upon the state in which the road-surface is kept. The gradient in all cases should be less than the *angle of repose*, or of that inclination of the axis of the road in which the ordinary vehicles for transportation would remain at a state of rest, or, if placed in motion, would descend by the action of gravity with uniform velocity.

The gradients corresponding to the angle of repose have been ascertained by experiments made upon the various road-coverings in ordinary use, by allowing a vehicle to descend along a road of variable inclination until it was brought to a state of rest by the retarding force of friction; also, by ascertaining the amount of force, termed *the force of traction*, requisite to put in motion a vehicle with a given load on a level road.

The following are the results of experiments made by Sir John Macneill, to determine the force of traction for one ton upon level roads.

No. 1.	Good pavement, the force of traction is	33 lbs.
" 2.	Broken stone surface laid on an old flint road	65 "
" 3.	Gravel road	147 "
" 4.	Broken stone surface on a rough pavement bottom	46 "
" 5.	Broken stone surface on a bottom of beton	46 "

From this it appears that the angle of repose in the first case is represented by $\frac{33}{2240}$, or $\frac{1}{68}$ nearly; and that the slope of the road should therefore not be greater than one perpendicular to sixty-eight in length; or that the height to be overcome must not be greater than one sixty-eighth of the distance between the two points measured along the road, in order that the force of friction may counteract that of gravity in the direction of the road.

A similar calculation will show that the angle of repose in the other cases will be as follows:—

No. 2, ...	1 to . . .	35 nearly.
" 3, ...	1 to . . .	15 "
" 4 and 5, . .	1 to . . .	49 "

These numbers, which give the angle of repose between $\frac{1}{35}$ and $\frac{1}{49}$ for the kinds of road-covering Nos. 2 and 4 in most ordinary use, and corresponding to a road-surface in good order, may be somewhat increased, to from $\frac{1}{28}$ to $\frac{1}{33}$, for the ordinary state of the surface of a well-kept road, without there being any necessity for applying a brake to the wheels in descending, or going out of a trot in ascending. The steepest gradient that can be allowed on roads with a broken-stone covering is about $\frac{1}{20}$, as this, from experience, is found to be about the angle of repose upon roads of this character in the state in which they are usually kept. Upon a road with this inclination, a horse can draw at a walk his usual load for a level without requiring the assistance of an extra horse; and experience has further shown that a horse at the usual walking pace will attain, with less apparent fatigue, the summit of a gradient of $\frac{1}{20}$ in nearly the same time that he would re-

quire to reach the same point on a trot over a gradient of $\frac{1}{33}$.

A road on a dead level, or one with a continued and uniform ascent between the points of arrival and departure, where they lie upon different levels, is not the most favourable to the draft of the horse. Each of these seems to fatigue him more than a line of alternate ascents and descents of slight gradients; as, for example, gradients of $\frac{1}{100}$, upon which a horse will draw as heavy a load with the same speed as upon a horizontal road.

The gradients should in all cases be reduced as far as practicable, as the extra exertion that a horse must put forth in overcoming heavy gradients is very considerable; they should, as a general rule, therefore, be kept as low at least as $\frac{1}{33}$, wherever the ground will admit of it. This can generally be effected, even in ascending steep hill-sides, by giving the axis of the road a zig-zag direction, connecting the straight portions of the zig-zags by circular arcs. The gradients of the curved portions of the zig-zags should be reduced, and the roadway also at these points be widened, for the safety of vehicles descending rapidly. The width of the roadway may be increased about one-fourth, when the angle between the straight portions of the zig-zags is from 120° to 90°; and the increase should be nearly one-half where the angle is from 90° to 60°.

Having laid down upon the map the approximate location of the axis of the road, a comparison can then be made between the solid contents of the excavations and embankments, which should be so adjusted that they shall balance each other, or, in other words, the necessary excavations shall furnish sufficient earth to form the embankments. To effect this, it will frequently be necessary to alter the first location, by shifting the position of the axis to the right or left of the position first assumed, and also by changing the gradients within the prescribed limits. This is a problem of very considerable intricacy, whose solution can only be arrived at by successive approximations. For this purpose, the line must be subdivided into several portions, in each of which the equalization should be attempted independently of the rest, instead of trying a general equalization for the whole line at once.

In the calculations of solid contents required in balancing the excavations and embankments, the most accurate method consists in subdividing the different solids into

others of the most simple geometrical forms, as prisms, prismoids, wedges, and pyramids, whose solidities are readily determined by the ordinary rules for the mensuration of solids. As this process, however, is frequently long and tedious, other methods requiring less time, but not so accurate, are generally preferred, as their results give an approximation sufficiently near the true for most practical purposes. They consist in taking a number of equidistant profiles, and calculating the solid contents between each pair, either by multiplying the half sum of their areas by the distance between them, or else by taking the profile at the middle point between each pair, and multiplying its area by the same length as before. The latter method is the more expeditious; it gives less than the true solid contents, but a nearer approximation than the former, which gives more than the true solid contents, whatever may be the form of the ground between each pair of cross profiles.

In calculating the solid contents, allowance must be made for the difference in bulk between the different kinds of earth when occupying their natural bed and when made into embankment. From some careful experiments on this point made by Mr. Elwood Morris, a civil engineer, and published in the Franklin Journal, it appears that light sandy earth occupies the same space both in excavation and embankment; clayey earth about one-tenth less in embankment than in its natural bed; gravelly earth also about one-twelfth less; rock in large fragments about five-twelfths more, and in small fragments about six-tenths more.

Another problem connected with the one in question, is that of determining the *lead*, or the mean distance to which the earth taken from the excavations must be carried to form the embankments. From the manner in which the earth is usually transported from the one to the other, this distance is usually that between the center of gravity of the solid of excavation and that of its corresponding embankment. Whatever disposition may be made of the solids of excavation, it is important, so far as the cost of their removal is concerned, that the lead should be the least possible. The solution of the problem under this point of view will frequently be extremely intricate, and demand the application of all the resources of the higher analysis. One general principle, however, is to be

observed in all cases, in order to obtain an approximate solution, which is, that in the removal of the different portions of the solid of excavation to their corresponding positions on that of the embankment, the paths passed over by their respective centers of gravity shall not cross each other either in a horizontal or vertical direction. This may in most cases be effected by intersecting the solids of excavation and embankment by vertical planes in the direction of the removal, and by removing the partial solids between the planes within the boundaries marked out by them.

The definite location having been settled by again going over the line, and comparing the features of the ground with the results furnished by the preceding operations, general and detailed maps of the different divisions of the definite location are prepared, which should give, with the utmost accuracy, the longitudinal and cross sections of the natural ground, and of the excavations and embankments, with the horizontal and vertical measurements carefully written upon them, so that the superintending engineer may have no difficulty in setting out the work from them on the ground.

In addition to these maps, which are mainly intended to guide the engineer in regulating the earth-work, detailed drawings of the road-covering, of the masonry and carpentry of the bridges, culverts, &c., accompanied by written specifications of the manner in which the various kind of work is to be performed, should be prepared for the guidance both of the engineer and workmen.

With the data furnished by the maps and drawings, the engineer can proceed to set out the line on the ground. The axis of the road is determined by placing stout stakes, or pickets, at equal intervals apart, which are numbered to correspond with the same points on the map. The width of the roadway and the lines on the ground corresponding to the side slopes of the excavations and embankments, are laid out in the same manner, by stakes placed along the lines of the cross profiles.

Besides the numbers marked on the stakes, to indicate their position on the map, other numbers, showing the depth of the excavations, or the height of the embankments from the surface of the ground, accompanied by the letters *Cutt. Fill.* to indicate a *cutting*, or a *filling*, as the case may be, are also added to guide the workmen in their opera-

tions. The positions of the stakes on the ground, which show the principal points of the axis of the road, should, moreover, be laid down on the map with great accuracy, by ascertaining their bearings and distances from any fixed and marked objects in their vicinity, in order that the points may be readily found should the stakes be subsequently misplaced.

Earth-work.—This term is applied to whatever relates to the construction of the excavations and embankments, to prepare them for receiving the road-covering.

In forming the excavations, the inclination of the side slopes demands peculiar attention. This inclination will depend on the nature of the soil, and the action of the atmosphere and internal moisture upon it. In common soils, as ordinary garden earth formed of a mixture of clay and sand, compact clay, and compact stony soils, although the side slopes would withstand very well the effects of the weather with a greater inclination, it is best to give them two base to one perpendicular; as the surface of the roadway will, by this arrangement, be well exposed to the action of the sun and air, which will cause a rapid evaporation of the moisture on the surface. Pure sand and gravel may require a greater slope, according to circumstances. In all cases where the depth of the excavation is great, the base of the slope should be increased. It is not usual to use any artificial means to protect the surface of the side slopes from the action of the weather; but it is a precaution which, in the end, will save much labour and expense in keeping the roadway in good order. The simplest means which can be used for this purpose, consists in covering the slopes with good sods, or else with a layer of vegetable mould about four inches thick, carefully laid and sown with grass seed. These means will be amply sufficient to protect the side slopes from injury when they are not exposed to any other causes of deterioration than the wash of the rain, and the action of frost on the ordinary moisture retained by the soil.

The side slopes form usually an unbroken surface from the foot to the top. But in deep excavations, and particularly in soils liable to slips, they are sometimes formed with horizontal offsets, termed *benches*, which are made a few feet wide and have a ditch on the inner side to receive the surface-water from the portion of the side slope above

them. These benches catch and retain the earth that may fall from the portion of the side slope above.

When the side slopes are not protected, it will be well, in localities where stone is plenty, to raise a small wall of dry stone at the foot of the slopes, to prevent the wash of the slopes from being carried into the roadway.

A covering of brush-wood, or a thatch of straw, may also be used with good effect; but, from their perishable nature, they will require frequent renewal and repairs.

In excavations through solid rock, which does not disintegrate on exposure to the atmosphere, the side slopes might be made perpendicular; but as this would exclude, in a great degree, the action of the sun and air, which is essential to keeping the road-surface dry and in good order, it will be necessary to make the side slopes with an inclination, varying from one base to one perpendicular, to one base to two perpendicular, or even greater, according to the locality; the inclination of the slope on the south side in northern latitudes being greatest, to expose better the road-surface to the sun's rays.

The slaty rocks generally decompose rapidly on the surface, when exposed to moisture and the action of frost. The side slopes in rocks of this character may be cut into steps, and then be covered by a layer of vegetable mould sown in grass seed, or else the earth may be sodded in the usual way.

The stratified soils and rocks, in which the strata have a *dip*, or inclination to the horizon, are liable to *slips*, or to give way, by one stratum becoming detached and sliding on another; which is caused either from the action of frost, or from the pressure of water, which insinuates itself between the strata. The worst soils of this character are those formed of alternate strata of clay and sand; particularly if the clay is of a nature to become semi-fluid when mixed with water. The best preventives that can be resorted to in these cases are, to adopt a thorough system of drainage, to prevent the surface-water of the ground from running down the side slopes, and to cut off all springs which run towards the roadway from the side slopes. The surface-water may be cut off by means of a single ditch made on the up-hill side of the road, to catch the water before it reaches the slope of the excavation, and convey it off to the natural water-courses most convenient; as, in almost

every case, it will be found that the side slope on the down-hill side is, comparatively speaking, but slightly affected by the surface-water.

Where slips occur from the action of springs, it frequently becomes a very difficult task to secure the side slopes. If the sources can be easily reached by excavating into the side slopes, drains formed of layers of fascines, or brush-wood, may be placed to give an outlet to the water, and prevent its action upon the side slopes. The fascines may be covered on top with good sods laid with the grass side beneath, and the excavation made to place the drain be filled in with good earth well rammed. Drains formed of broken stone, covered in like manner on top with a layer of sod to prevent the drain from becoming choked with earth, may be used under the same circumstances as fascine drains. Where the sources are not isolated, and the whole mass of the soil forming the side slopes appears saturated, the drainage may be effected by excavating trenches a few feet wide at intervals to the depth of some feet into the side slopes, and filling them with broken stone, or else a general drain of broken stone may be made throughout, the whole extent of the side slope by excavating into it. When this is deemed necessary, it will be well to arrange the drain like an inclined retaining-wall, with buttresses at intervals projecting into the earth further than the general mass of the drain. The front face of the drain should, in this case, also be covered with a layer of sods with the grass side beneath, and upon this a layer of good earth should be compactly laid to form the face of the side slopes. The drain need only be carried high enough above the foot of the side slope to tap all the sources; and it should be sunk sufficiently below the roadway surface to give it a secure footing.

The drainage has been effected, in some cases, by sinking wells or *shafts* at some distance behind the side slopes, from the top surface to the level of the bottom of the excavation, and leading the water which collects in them by pipes into drains at the foot of the side slopes. In others, a narrow trench has been excavated, parallel to the axis of the road, from the top surface to a sufficient depth to tap all the sources which flow towards the side slope, and a drain formed either by filling the trench wholly with broken stone, or else by arranging an open conduit at the bottom to receive the water collected, over which a layer

of brush-wood is laid, the remainder of the trench being filled with broken stone.

In some recent instances in England, the side slopes of very bad soils have been secured by a facing of brick arranged in a manner very similar to the method resorted to for securing the perpendicular sides of narrow deep trenches by a timber-facing. The plan pursued is, to place, at intervals along the excavation, strong buttresses of brick on each side, opposite to each other, and to connect them at bottom by a reversed arch. Between these buttresses are placed, at suitable heights, one or more brick beams, formed at bottom with a flat segment arch, and at top with a like inverted arch. The buttresses, secured in this way, serve as piers for vertical cylindrical arches, which form the facing and support the pressure of the earth between the buttresses.

In forming the embankments, the side slopes should be made with a less inclination than that which the earth naturally assumes; for the purpose of giving them greater durability, and to prevent the width of the top surface, along which the roadway is made, from diminishing by every change in the side slopes, as it would were they made with the natural slope. To protect the side slopes more effectually, they should be sodded, or sown in grass seed; and the surface-water of the top should not be allowed to run down them, as it would soon wash them into gullies, and destroy the embankment. In localities where stone is plenty, a sustaining wall of dry stone may be advantageously substituted for the side slopes.

To prevent, as far as possible, the settling which takes place in embankments, they should be formed with great care; the earth being laid in successive layers of about four feet in thickness, and each layer well settled with rammers. As this method is very expensive, it is seldom resorted to except in works which require great care, and are of trifling extent. For extensive works, the method usually followed, on account of economy, is to embank out from one end, carrying forward the work on a level with the top surface. In this case, as there must be a want of compactness in the mass, it would be best to form the outsides of the embankment first, and to gradually fill in towards the center, in order that the earth may arrange itself in layers with a dip from the sides inwards; this will in a great measure counteract any tendency to slips outward. The foot of the

slopes should be secured by buttressing them either by a low stone wall, or by forming a slight excavation for the same purpose.

When the axis of the roadway is laid out on the side slope of a hill, and the road-surface is formed partly by excavating and partly by embanking out, the usual and most simple method is to extend out the embankment gradually along the whole line of excavation. This method is insecure, and no pains therefore should be spared to give the embankment a good footing on the natural surface upon which it rests, particularly at the foot of the slope. For this purpose the natural surface should be cut into steps, or offsets, and the foot of the slope be secured by buttressing it against a low stone wall, or a small terrace of carefully rammed earth.

In side-formings along a natural surface of great inclination, the method of construction just explained will not be sufficiently secure; sustaining-walls must be substituted for the side slopes, both of the excavations and embankments. These walls may be made simply of dry stone, when the stone can be procured in blocks of sufficient size to render this kind of construction of sufficient stability to resist the pressure of the earth. But when the blocks of stone do not offer this security, they must be laid in mortar, and hydraulic mortar is the only kind which will form a safe construction. The wall which supplies the slope of the excavation should be carried up as high as the natural surface of the ground; the one that sustains the embankment should be built up to the surface of the roadway; and a parapet-wall should be raised upon it, to secure vehicles from accidents in deviating from the line of the roadway.

A road may be constructed partly in excavation and partly in embankment along a rocky ledge, by blasting the rock, when the inclination of the natural surface is not greater than one perpendicular to two base; but with a greater inclination than this, the whole should be in excavation.

There are examples of road constructions, in localities like the last, supported on a frame-work, consisting of horizontal pieces, which are firmly fixed at one end by being let into holes drilled in the rock, and are sustained at the other by an inclined strut underneath, which rests against the rock in a shoulder formed to receive it.

When the excavations do not furnish sufficient earth for the embankments, it is obtained from excavations termed *side-cuttings*, made at some place in the vicinity of the embankment, from which the earth can be obtained with the most economy.

If the excavations furnish more earth than is required for the embankment, it is deposited in what is termed a *spoil-bank*, on the side of the excavation. The spoil-bank should be made at some distance back from the side slope of the excavation, and on the down-hill side of the top-surface; and suitable drains should be arranged to carry off any water that might collect near it and affect the side slope of the excavation.

The forms to be given to side-cuttings and spoil-banks will depend, in a great degree, upon the locality: they should, as far as practicable, be such that the cost of removal of the earth shall be least possible.

Drainage.—A system of thorough drainage, by which the water that filters through the ground will be cut off from the soil beneath the roadway, to a depth of at least three feet below the bottom of the road-covering, and by which that which falls upon the surface will be speedily conveyed off, before it can filter through the road-covering, is essential to the good condition of a road.

The surface-water is conveyed off by giving the surface of the roadway a slight transverse convexity, from the middle to the sides, where the water is received into the gutters, or *side channels*, from which it is conveyed by underground aqueducts, termed *culverts*, built of stone or brick, and usually arched at top, into the main drains that communicate with the natural water-courses. This convexity is regulated by making the figure of the profile an ellipse, of which the semi-tranverse axis is 15 feet, and the semi-conjugate axis 9 inches; thus placing the middle of the roadway nine inches above the bottom of the side channels. This convexity, which is as great as should be given, will not be sufficient in a flat country to keep the road-surface dry; and in such localities, if a slight longitudinal slope cannot be given to the road, it should be raised, when practicable, three or four feet above the general level; both on account of conveying off speedily the surface-water, and exposing the surface better to the action of the wind.

To drain the soil beneath the roadway in a level country,

ditches, termed *open side drains*, are made parallel to the road, and at some feet from it on each side. The bottom of the side drains should be at least three feet below the road-covering; their size will depend on the nature of the soil to be drained. In a cultivated country the side drains should be on the field side of the fences.

As open drains would be soon filled along the parts of a road in excavation, by the washings from the side slopes, covered drains, built either of brick or stone, must be substituted for them. Such drains consist simply of a flooring of flagging stone, or of brick, with two side walls of rubble, or brick masonry, which support a top covering of flat stones, or of brick, with open joints, of about half an inch, to give a free passage-way to the water into the drain. The top is covered with a layer of straw or brushwood; and clean gravel, or broken stone, in small fragments, is laid over this, for the purpose of allowing the water to filter freely through to the drain, without carrying with it any earth or sediment, which might in time accumulate and choke it. The width and height of covered drains will depend on the materials of which they are built, and the quantity of water to which they yield a passage.

Besides the longitudinal covered drains in cuttings, other drains are made under the roadway, which, from their form, are termed *cross mitre drains*. Their plan is in shape like the letter V, the angular point being at the centre of the road, and pointing in the direction of its ascent. The angle should be so regulated that the bottom of the drain shall not have a greater slope along either of its branches, than one perpendicular to one hundred base, to preserve the masonry from damage by the current. The construction of mitre drains is the same as the covered longitudinal drains. They should be placed at intervals of about sixty yards from each other.

In some cases surface drains, termed *catch-water drains*, are made on the side slopes of cuttings. They are run up obliquely along the surface, and empty directly into the cross drains which convey the water into the natural water-courses.

When the roadway is in side-forming, cross drains of the ordinary form of culverts are made, to convey the water from the side channels and the covered drains into the natural water-courses. They should be of sufficient di-

mensions to convey off a large volume of water, and to admit a man to pass through them so that they may be readily cleared out, or even repaired, without breaking up the roadway over them.

The only drains required for embankments are the ordinary side channels of the roadway, with occasional culverts, to convey the water from them into the natural water-courses. Great care should be taken to prevent the surface-water from running down the side slopes, as they would soon be washed into gullies by it.

Very wet and marshy soils require to be thoroughly drained before the roadway can be made with safety. The best system that can be followed in such cases, is to cut a wide and deep open main drain on each side of the road, to convey the water to the natural water-courses. Covered cross drains should be made at frequent intervals, to drain the soil under the roadway. They should be sunk as low as will admit of the water running from them into the main drains, by giving a slight slope to the bottom each way from the center of the road to facilitate its flow.

Independently of the drainage for marshy soils, they will require, when the subsoil is of a spongy elastic nature, an artificial bed for the road-covering. This bed may, in some cases, be formed by simply removing the upper stratum to a depth of several feet, and supplying its place with well-packed gravel, or any soil of a firm character. In other cases, when the subsoil yields readily to the ordinary pressure that the road-surface must bear, a bed of brushwood, from nine to eighteen inches in thickness, must be formed to receive the soil on which the road-covering is to rest. The brushwood should be carefully selected from the long straight slender shoots of the branches or undergrowth, and be tied up in bundles, termed *fascines*, from nine to twelve inches in diameter, and from ten to twenty feet long. The fascines are laid in alternate layers crosswise and lengthwise, and the layers are either connected by pickets, or else the withes, with which the fascines are bound, are cut to allow the brushwood to form a uniform and campact bed.

This method of securing a good bed for structures on a weak wet soil has been long practised in Holland, and experience has fully tested its excellence.

Road-coverings. — The object of a road-covering being to diminish the resistances arising from collision and

friction, and thereby to reduce the force of traction to the least practicable amount, it should be composed of hard and durable materials, laid on a firm foundation, and present a uniform, even surface.

The material in ordinary use for road-coverings is stone, either in the shape of blocks of a regular form, or of large round pebbles, termed a *pavement;* or broken into small angular masses; or in the form of gravel.

Pavements.—The pavements in most general use in our country are constructed of rounded pebbles, known as *paving-stones*, varying from three to eight inches in diameter, which are set in a *form*, or bed of clean sand or gravel, a foot or two in thickness, which is laid upon the natural soil excavated to receive the form. The largest stones are placed in the center of the roadway. The stones are carefully set in the form, in close contact with each other, and are then firmly settled by a heavy rammer until their tops are even with the general surface of the roadway, which should be of a slightly convex shape, having a slope of about $\frac{1}{48}$ from the center each way to the sides. After the stones are driven, the road-surface is covered with a layer of clean sand, or fine gravel, two or three inches in thickness, which is gradually worked in between the stones by the combined action of the travel over the pavement and of the weather.

The defects of pebble pavements are obvious, and confirmed by experience. The form of sand or gravel, as usually made, is not sufficiently firm; it should be made in separate layers of about four inches, each layer being moistened and well settled either by ramming, or passing a heavy roller over it. Upon the form prepared in this way a layer of loose material of two or three inches in thickness may be placed, to receive the ends of the paving-stones. From the form of the pebbles, the resistance to traction arising from collision and friction is very great.

Pavements termed *stone tramways* have been tried in some of the cities of Europe, both for light and heavy traffic. They are formed by laying two lines of long stone blocks for the wheels to run on, with a pavement of pebble for the horse-track between the wheel-tracks. In crowded thoroughfares tramways offer but few if any advantages, as it is impracticable to confine the vehicles to them, and when exposed to heavy traffic they wear into ruts. The stone blocks should be carefully laid on a very firm bottom-

ing, and particular attention is requisite to prevent ruts from forming between the blocks and the pebble pavement.

Stone suitable for pavements should be hard and tough, and not wear smooth under the action to which it is exposed. Some varieties of granite have been found in England to furnish the best paving blocks. In France, a very fine-grained compact gray sandstone of a bluish cast is mostly in use for the same purpose, but it wears quite smooth.

The sand used for forms should be clean and free from pebbles and gravel of a larger grain than about two-tenths of an inch. The form should be made by moistening the sand, and compressing it in layers of about four inches in thickness, either by ramming, or by passing over each layer several times a heavy iron roller. Upon the top layer about an inch of loose sand may be spread to receive the blocks; the joints between which, after they are placed, should be carefully filled with sand.

The sand form, when carefully made, presents a very firm and stable foundation for the pavement.

Wooden pavements, formed of blocks of wood of various shapes, have been tried in England, and several of the cities of the United States, within the last few years, but are now for the most part abandoned, as the material has been found to decay very rapidly, even when prepared with some of the preservatives of timber against the rot.

Asphaltic pavements have undergone a like trial, and have also been found to fail after a few years' service. This material is further objectionable as a pavement in cities, where the pavements and sidewalks have frequently to be disturbed for the purposes of repairing, or laying down sewers, water-pipes, and other necessary conveniences.

The best system of pavement is that which has been partially put in practice in some of the commercial cities of England, the idea of which seems to have been taken from the excellent military roads of the Romans, vestiges of which remain at the present day in a good state.

In constructing this pavement, a bed is first prepared, by removing the surface of the soil to the depth of a foot or more, to obtain a firm stratum; the surface of this bed receives a very slight convexity, of about two inches to ten feet, from the center to the sides of the roadway. If the

soil is of a soft clayey nature, into which small fragments of broken stone would be easily worked by the wheels of vehicles, it should be excavated a foot or two deeper to receive a form of sand, or of clean fine gravel. On the surface of the bed thus prepared, a layer of small broken stone, four inches thick, is laid; the dimensions of these fragments should not be greater than two and a half inches in any direction; the road is then opened to vehicles until this first layer becomes perfectly compact; care being taken to fill up any ruts with fresh stone, in order to obtain an uniform surface. A second layer of stone, of the same thickness as the first, is then laid on, and treated in the same manner; and, finally, a third layer. When the third layer has become perfectly compact, and is of an uniform surface, a layer of fine clean gravel, two and a half inches thick, is spread evenly over it to receive the paving-stones. The blocks of stone are of a square shape, and of different sizes, according to the nature of the travelling over the pavement. The largest size are ten inches thick, nine inches broad, and twelve inches long; the smallest are six inches thick, five inches broad, and ten inches long. Each block is carefully settled in the form, by means of a heavy beetle; it is then removed in order to cover the side of the one against which it is to rest with hydraulic mortar; this being done, the block is replaced, and properly adjusted. The blocks of the different courses across the roadway should break joints. The surface of the road is convex; the convexity being determined by making the outer edges six inches lower than the middle, for a width of thirty feet.

This system of pavement fulfils in the best manner all the requisites of a good road-covering, presenting a hard even surface to the action of the wheels, and reposing on a firm bed formed by the broken-stone bottoming. The mortar-joints, so long as they remain tight, will effectually prevent the penetration of water beneath the pavement; but it is probable, from the effect of the transit of heavily-laden vehicles, and from the expansion and contraction of the stone, which in our climate is found to be very considerable, that the mortar would soon be crushed and washed out.

In France, and in many of the large cities of the Continent, the pavements are made with blocks of rough stone

of a cubical form, measuring between eight and nine inches along the edge of the cube. These are laid on a form of sand of only a few inches thick when the soil beneath is firm; but in bad soils the thickness is increased to from six to twelve inches. The transversal joints are usually continuous, and those in the direction of the axis of the road break joints. In some cases the blocks are so laid that the joints make an angle of 45° with the axis of the roadway, one set being continuous, the other breaking joints with them. By this arrangement of the joints, it is said that the wear upon the edges of the blocks, by which the upper surface soon assumes a convex shape, is diminished. It has been ascertained by experience, that the wear upon the edges of the blocks is greatest at the joints which run transversely to the axis when the blocks are laid in the usual manner. From the experiments of M. Morin, to ascertain the influence of the shape of stone blocks on the force of traction, it was found that the resistance offered by a pavement of blocks averaging from five to six inches in breadth, measured in the direction of the axis of the roadway, and about nine inches in length, was less than in one of cubical blocks of the ordinary size.

Pavements in cities must be accompanied by sidewalks, and crossing-places, for foot-passengers. The sidewalks are made of large flat flagging-stone, at least two inches thick, laid on a form of clean gravel well rammed and settled. The width of the sidewalks will depend on the street being more or less frequented by a crowd. It would, in all cases, be well to have them at least twelve feet wide; they receive a slope, or pitch, of one inch to ten feet, towards the pavement, to convey the surface-water to the side channels. The pavement is separated from the sidewalk by a row of long slabs set on their edges, termed *curb-stones*, which confine both the flagging and paving-stones. The curb-stones form the sides of the side channels, and should for this purpose project six inches above the outside paving-stones, and be sunk at least four inches below their top surface; they should, moreover, be flush with the upper surface of the sidewalks, to allow the water to run over into the side channels, and to prevent accidents which might otherwise happen from their tripping persons passing in haste.

The crossings should be from four to six feet wide, and be slightly raised above the general surface of the pavement, to keep them free from mud.

Broken stone road-covering.—The ordinary road-covering for common roads, in use in this country and Europe, is formed of a coating of stone broken into small fragments, which is laid either upon the natural soil, or upon a paved bottoming of small irregular blocks of stone. In England these two systems have their respective partisans; the one claiming the superiority for road-coverings of stone broken into small fragments, a method brought into vogue some years since by Sir J. McAdam, from whom these roads have been termed *macadamized*; the other being the plan pursued by the late Mr. Telford in the great national roads constructed in Great Britain within about the same period.

The subject of road-making has within the last few years excited renewed interest and discussion among engineers in France; the conclusion, drawn from experience, there generally adopted is, that a covering alone of stone broken into small fragments is sufficient under the heaviest traffic and most frequented roads. Some of the French engineers recommend, in very yielding clayey soils, that either a paved bottoming after Telford's method be resorted to, or that the soil be well compressed at the surface before placing the road-covering.

The paved bottom road-covering on Telford's plan is formed by excavating the surface of the ground to a suitable depth, and preparing the form for the pavement with the precautions as for a common pavement. Blocks of stone of an irregular pyramidal shape are selected for the pavement, which, for a roadway thirty feet in width, should be seven inches thick for the center of the road, and three inches thick at the sides. The base of each block should not measure more than five inches, and the top not less than four inches.

The blocks are set by the hand, with great care, as closely in contact at their bases as practicable; and blocks of a suitable size are selected to give the surface of the pavement a slightly convex shape from the center outwards. The spaces between the blocks are filled with chippings of stone compactly set with a small hammer.

A layer of broken stone, four inches thick, is laid over this pavement, for a width of nine feet on each side of the

center; no fragment of this layer should measure over two and a half inches in any direction. A layer of broken stone of smaller dimensions, or of clean coarse gravel, is spread over the wings to the same depth as the center layer.

The road-covering, thus prepared, is thrown open to vehicles until the upper layer has become perfectly compact; care having been taken to fill in the ruts with fresh stone, in order to obtain an uniform surface. A second layer, about two inches in depth, is then laid over the center of the roadway; and the wings receive also a layer of new material laid on to a sufficient thickness to make the outside of the roadway nine inches lower than the center, by giving a slight convexity to the surface from the center outwards. A coating of clean coarse gravel, one inch and a half thick, termed a *binding*, is spread over the surface, and the road-covering is then ready to be thrown open to travelling.

The stone used for the pavement may be of an inferior quality, in hardness and strength, to that placed at the surface, as it is but little exposed to the wear and tear occasioned by travelling. The surface-stone should be of the hardest kind that can be procured. The gravel binding is laid over the surface to facilitate the travelling, whilst the under stratum of stone is still loose; it is, however, hurtful, as, by working in between the broken stones, it prevents them from setting as compactly as they would otherwise do.

If the roadway cannot be paved the entire width, it should, at least, receive a pavement for the width of nine feet on each side of the center. The wings, in this case, may be formed entirely of clean gravel, or of chippings of stone.

For roads which are not much travelled, like the ordinary cross roads of the country, the pavement will not demand so much care; but may be made of any stone at hand, broken into fragments of such dimensions that no stone shall weigh over four pounds. The surface-coating may be formed in the manner just described.

In forming a road-covering of broken stone alone, the bed for the covering is arranged in the same manner as for the paved bottoming: a layer of the stone, four inches in thickness, is carefully spread over the bed, and the road is thrown open to vehicles, care being taken to fill the ruts, and preserve the surface in a uniform state until the

layer has become compact; successive layers are laid on and treated in the same manner as the first, until the covering has received a thickness of about twelve inches in the center, with the ordinary convexity at the surface.

Where good gravel can be procured the road-covering may be made of this material, which should be well screened, and all pebbles found in it over two and a half inches in diameter should be broken into fragments of not greater dimensions than these. A firm level form having been prepared, a layer of gravel, four inches in thickness, is laid on, and, when this has become compact from the travel, successive layers of about three inches in thickness are laid on and treated like the first, until the covering has received a thickness of sixteen inches in the center and the ordinary convexity.

As has been already stated, the French civil engineers do not regard a paved bottoming as essentials for broken stone road-coverings, except in cases of a very heavy traffic, or where the substratum of the road is of a very yielding character. They also give less thickness to the road-covering than the Telford's school deem necessary; allowing not more than six to eight inches to road-coverings for light traffic, and about ten inches only for the heaviest traffic.

If the soil upon which the road-covering is to be placed is not dry and firm, they compress it by rolling, which is done by passing over it several times an iron cylinder, about six feet in diameter, and four feet in length, the weight of which can be increased, by additional weights, from six thousand to about twenty thousand pounds. The road material is placed upon the bed, when well compressed and levelled, in layers of about four inches, each layer being compressed by passing the cylinder several times over it before a new one is laid on. If the operation of rolling is performed in dry weather, the layer of stone is watered, and some add a thin layer of clean sand, from four to eight-tenths of an inch in thickness, over each layer before it is rolled, for the purpose of consolidating the surface of the layer, by filling the voids between the broken stone fragments. After the surface has been well consolidated by rolling, the road is thrown open for travel, and all ruts and other displacement of the stone on the surface are carefully repaired, by adding fresh material, and levelling the ridges by ramming.

Great importance is attached by the French engineers to the use of the iron cylinder for compressing the materials of a new road, and to minute attention to daily repairs. It is stated that by the use of the cylinder the road is presented at once in a good travelling condition; the wear of the materials is less than by the old method of gradually consolidating them by the travel; the cost of repairs during the first years is diminished; it gives to the road-covering a more uniform thickness, and admits of its being thinner than in the usual method.

Materials and Repairs.—The materials for broken stone roads should be hard and durable. For the bottom layer a soft stone, or a mixture of hard and soft, may be used, but on the surface none but the hardest stone will withstand the action of the wheels. The stone should be carefully broken into fragments of nearly as cubical a form as practicable, and be cleansed from dirt and of all very small fragments. The broken stone should be kept in depôts at convenient points along the line of the road, for repairs.

Too great attention cannot be bestowed upon keeping the road-surface free from an accumulation of mud and even of dust. It should be constantly cleaned by scraping and sweeping. The repairs should be daily made by adding fresh material upon all points where hollows or ruts commence to form. It is recommended by some that when fresh material is added, the surface on which it is spread should be broken with a pick to the depth of half an inch to an inch, and the fresh material be well settled by ramming, a small quantity of clean sand being added to make the stone pack better. When not daily repaired by persons whose sole business it is to keep the road in good order, general repairs should be made in the months of October and April, by removing all accumulations of mud, cleaning out the side channels and other drains, and adding fresh material where requisite.

The importance of keeping the road-surface at all times free from an accumulation of mud and dust, and of preserving the surface in a uniform state of evenness, by the daily addition of fresh material wherever the wear is sufficient to call for it, cannot be too strongly insisted upon. Without this constant supervision, the best-constructed road will, in a short time, be unfit for travel, and with it the weakest may at all times be kept in a tolerably fair state.

Cross dimensions of Roads.—A road thirty feet in width is amply sufficient for the carriage-way of the most frequented thoroughfares between cities. A width of forty, or even sixty feet, may be given near cities, where the greater part of the transportation is effected by land. For cross roads, and others of minor importance, the width may be reduced according to the nature of the case. The width should be at least sufficient to allow two of the ordinary carriages of the country to pass each other with safety. In all cases, it should be borne in mind that any unnecessary width increases both the first cost of construction and the expense of annual repairs.

Very wide roads have in some cases been used, the center part only receiving a road-covering, and the wings, termed *summer roads*, being formed on the natural surface of the subsoil. The object of this system is to relieve the road-covering from the wear and tear occasioned by the lighter kind of vehicles during the summer, as the wings present a more pleasant surface for travelling in that season. But little is gained by this system under this point of view; and it has the inconvenience of forming during the winter a large quantity of mud, which is very injurious to the road-covering.

There should be at least one footpath, from five to six feet wide, and not more than nine inches higher than the bottom of the side channels. The surface of the footpath should have a pitch of two inches, towards the side channels, to convey its surface-water into them. When the natural soil is firm and sandy, or gravelly, its surface will serve for the footpath; but in other cases the natural soil must be thrown out to a depth of six inches, and the excavation filled with fine clean gravel.

To prevent the footpath from being damaged by the current of water in the side channels, its side slope, next to the side channel, must be protected by a facing of good sods, or of dry stone.

As it is of the first importance, in keeping the roadway in a good travelling state, that its surface should be kept dry, it will be necessary to remove from it, as far as practicable, all objects that might obstruct the action of the wind and the sun on its surface. Fences and hedges along the road should not be higher than five feet; and no trees should be suffered to stand on the road-side of the side drains, for, independently of shading the

roadway, their roots would in time throw up the road-covering.

Plank Roads.—A road-covering, consisting of thick boards, or planks, resting on longitudinal beams, or sleepers, and known as *plank roads*, has, within the past few years, been introduced among us; and from its adaptation to our uncleared forest districts, its superior economy to the ordinary road-coverings in such localities, and its intrinsic merits, as fulfilling the requisites of a good road-covering, is rapidly coming into extensive use throughout all parts of the United States.

The method most generally adopted in constructing plank roads consists in laying a flooring, or track, eight feet wide, composed of boards from nine to twelve inches in width, and three inches in thickness, which rest upon two parallel rows of sleepers, or sills, laid lengthwise of the road, and having their center lines about four feet apart, or two feet from the axis of the road. Sills of various-sized scantling have been used, but experience seems in favour of scantling about twelve inches in width, four inches in thickness, and in lengths of not less than fifteen to twenty feet. Sills of these dimensions, laid flatwise, and firmly imbedded, present a firm and uniform bearing to the boards, and distribute the pressure they receive over so great a surface, that, if the soil upon which they rest is compact and kept well drained, there can be but little settling and displacement of the road-surface, from the usual loads passing over it. The better to secure this uniform distribution of the pressure, the sills of one row are so laid as to break joints with the other; and to prevent the ends of the sills from yielding, the usual precaution is taken to place short sills at the joints, either beneath the main sills, or on the same level with them.

The boards are laid perpendicular to the axis of the road, experience having shown that this position is as favourable to their wear and tear as any other, and is otherwise the most economical. Their ends are not in an unbroken line, but so arranged that the ends of every three or four project alternately, on each side of the axis of the road, three or four inches beyond those next to them, for the purpose of presenting a short shoulder to the wheels of vehicles, to facilitate their coming upon the plank surface, when from any cause they may have turned aside. On some roads the boards have been spiked to the

sills; but this is, at present, regarded as unnecessary, the stability of the boards being best secured by well packing the earth between and around the sills, so as to present, with them, a uniform bearing surface to the boards, and by adopting the usual precautions for keeping the subsoil well drained, and preventing any accumulation of rain-water on the surface.

The boards for plank roads should be selected from timber free from the usual defects, such as knots, shakes, &c., which would render it unsuitable for ordinary building purposes; as durability is an essential element in the economy of this class of structures. So far as experience has furnished data, boards of three inches in thickness offer all the requisites of strength and durability that can be obtained from timber in its ordinary state, in which it is used for plank roads.

Besides the wooden track of eight feet, an earthen track of twelve feet in width is made, which serves as a summer road for light vehicles, and as a turn-out for loaded ones; this, with the wooden track, gives a clear road-surface of twenty feet, the least that can be well allowed for a frequented road. It is recommended to lay the wooden track on the right hand side of the approach of a road to a town, or village, for the proper convenience of the rural traffic, as the heavy trade is to the town. The surface of this track receives a cross slope from the side towards the axis of the road outwards of 1 in 32. The surface of the summer road receives a cross slope in the opposite direction of 1 in 16. These slopes are given for the purpose of facilitating a rapid surface drainage. The side drains are placed for this purpose parallel to the axis of the road, and connected with the road-surface in a suitable slope.

Where, from the character of the soil, good summer roads cannot be had, it will be necessary to make wooden turn-outs, from space to space, to prevent the inconvenience and delay of miry roads. This it is proposed to do by laying, at these points, a wooden track of double width, to enable vehicles meeting to pass each other. It is recommended to lay these turn-outs on four or five sills, to spring the boards slightly at the center, and spike their ends to the exterior sills.

The angle of repose, by which the grade of plank roads should be regulated, has not yet been determined by ex-

periment; but as the wooden surface is covered with a layer of clean sand, fine gravel, or tan bark, before it is thrown open to vehicles, and as it in time becomes covered with a permanent stratum of dust, &c., it is probable that this angle will not materially differ from that on a road with a broken stone surface, like the one of McAdam, or of Telford, when kept in a thorough state of repair.

In some of the earlier plank roads made in Canada, a width of sixteen feet was given to the wooden track, the boards of which were laid upon four or five rows of sills; experience soon demonstrated that this was by no means an economical plan, as it was found that vehicles kept the center of the wooden surface, which was soon worn into a beaten track, whilst the remainder was but slightly impaired. This led to the abandonment of the wide track for the one now usually adopted, which answers all the ends of the wants of travel, and is much more economical, both in the first outlay and for subsequent renewals.

The great advantages of plank roads over every other kind, in a densely-wooded country, for the rural traffic, are so obvious, that, did not experience teach us by what mere accidents, apparently, improvements of the most important kind have been suggested and carried into effect, it might be a subject of astonishment that they had not been among the first to be introduced, after a trial of the old *corduroy* roads, so generally resorted to in the early stages of road-making in the United States.

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